

# PATENT ABSTRACTS OF JAPAN

(11)Publication number : 10-090600

(43)Date of publication of application : 10.04.1998

(51)Int.CI.

G02B 15/20  
G02B 13/18

(21)Application number : 08-241472

(71)Applicant : NIKON CORP

(22)Date of filing : 12.09.1996

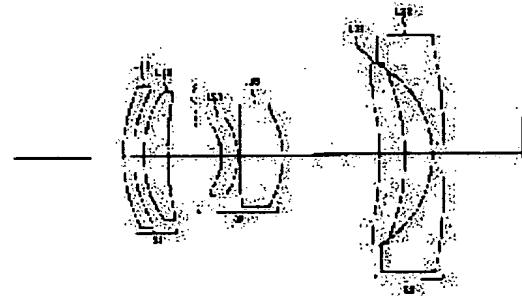
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## (54) VARIABLE MAGNIFICATION OPTICAL SYSTEM

### (57)Abstract:

**PROBLEM TO BE SOLVED:** To provide a variable magnification optical system suitable to miniaturization and low cost formation.

**SOLUTION:** This variable magnification optical system is constituted of a first lens group G1 having positive refractive power, a second lens group G2 having the positive refractive power and a third lens group G3 having negative refractive power in order from an object side, and when a lens position state is changed from a wide-angle end state to a telephoto-end state, all lens groups are moved to the object side so that an interval between the first lens group G1 and the second lens group G2 is increased, and the interval between the second lens group G2 and the third lens group G3 is reduced. Then, the second lens group G2 is constituted of only a negative lens component turning a concave surface to the object side and a positive lens component turning a convex surface to an image side, and prescribes the range of the suitable focal distance of the first lens group G1.



## LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's  
decision of rejection]

[Date of extinction of right]

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## CLAIMS

## [Claim(s)]

[Claim 1] Body sides are consisted of by the 3rd lens group which has in order the 1st lens group which has right refractive power, the 2nd lens group which has right refractive power, and negative refractive power. So that the interval of the aforementioned 1st lens group and the aforementioned 2nd lens group may increase and the interval of the aforementioned 2nd lens group and the aforementioned 3rd lens group may decrease, in case a lens position state changes from a wide angle edge state to a tele edge state. It is the variable power optical system characterized by for all lens groups moving to a body side, and for the aforementioned 2nd lens group consisting of only a negative-lens component which turned the concave surface to the body side, and a positive-lens component which turned the convex to the image side, and satisfying the following conditional expression (1).

## [Equation 1]

$$(1) 0.9 < f_1 / (f_w \cdot f_t)^{1/2} < 2.0$$

However,  $f_1$  : Focal distance  $f_w$  of the aforementioned 1st lens group: Focal distance  $f_t$  in the whole system in the wide angle edge state of the aforementioned variable power optical system: It is a focal distance in the whole system in the tele edge state of the aforementioned variable power optical system.

[Claim 2] It is the variable power optical system according to claim 1 characterized by the aforementioned aperture diaphragm moving in one with the aforementioned 2nd lens group in case it has further the aperture diaphragm which adjoined the aforementioned 2nd lens group and has been arranged and a lens position state changes.

[Claim 3] The lens side in which it separates from the aforementioned aperture diaphragm most among the lens sides in the aforementioned 2nd lens group, and is located is variable power optical system according to claim 2 characterized by being the aspheric surface.

[Claim 4] The aforementioned aperture diaphragm is variable power optical system according to claim 2 or 3 characterized by being arranged between the aforementioned 1st lens group and the aforementioned 2nd lens group.

[Claim 5] The aforementioned 1st lens group is variable power optical system according to claim 1 or 4 characterized by consisting of only a negative-lens component and a positive-lens component arranged at the image side.

[Claim 6] Variable power optical system according to claim 1 or 5 characterized by satisfying the following conditional expression (2).

(2)  $0.6 < (T_{Lt} - T_{Lw}) / (f_t - f_w) < 0.9$ , however the lens overall length  $T_{Lw}$  in a  $T_{Lt}$ :tele edge state : it is a lens overall length in a wide angle edge state.

[Claim 7] Variable power optical system according to claim 6 characterized by satisfying the following conditional expression (3).

(3)  $\beta_{3w} > 1.40$ , however  $\beta_{3w}$ : It is the lateral magnification of the aforementioned 3rd lens group in a wide angle edge state. [Claim 8] The 2nd lens group is variable power optical system according to claim 1 characterized by moving by the movement magnitude ratio from which the aforementioned aperture diaphragm differs in case it has further the aperture diaphragm

arranged between the aforementioned 1st lens group and the aforementioned 2nd lens group and a lens position state changes from a wide angle edge state to a tele edge state.

[Claim 9] Variable power optical system according to claim 1 or 8 characterized by satisfying the following conditional expression (4).

(4)  $0.5 < (D1T - D1W) / (D2W - D2T) < 2$  -- however D1T : In the tele edge state the aforementioned 1st lens group which can be set -- most -- the field by the side of an image -- length D1W of the aforementioned 2nd lens group which met the optical axis to the field by the side of a body most : the aforementioned 1st lens group in a wide angle edge state -- most -- the field by the side of an image -- length D2T of the aforementioned 2nd lens group which met the optical axis to the field by the side of a body most : In the tele edge state It is length D2W of the aforementioned 3rd lens group which met the optical axis to the field by the side of a body most from the field by the side of the aforementioned 2nd lens group which can be set, but an image. : It is the length of the aforementioned 3rd lens group which met the optical axis to the field by the side of a body most from the field by the side of the aforementioned 2nd lens group in a wide angle edge state, but an image.

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[Translation done.]

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## DETAILED DESCRIPTION

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### [Detailed Description of the Invention]

#### [0001]

[The technical field to which invention belongs] this invention relates to the variable power optical system which includes the field angle which exceeds 65 degrees especially in a wide angle edge state about small variable power optical system.

#### [0002]

[Description of the Prior Art] In the taking lens for the latest lens shutter formula cameras, a zoom lens becomes general and the camera equipped with the high variable power zoom lens with which a variable power ratio exceeds double precision is becoming in use. Conventionally, 2 group zoom lens which consists of a positive-lens group and a negative-lens group is known. change of the aberration outside a shaft accompanying [ when it is going to raise a variable power ratio with this 2 group zoom lens ] change of a lens position state — good — an amendment — the problem to which things become difficult — or the movement magnitude at the time of a lens position state changing from a wide-angle edge state (state where of a focal distance is the shortest), to a tele-edge state (state where of a focal distance is the longest) became large, and problems, such as causing complication of lens-barrel structure, had arisen

[0003] Moreover, since the degree of option arises on move tracing (zoom orbit) which the multi-group zoom lens has three or more moving-lens groups, and each lens group moves from a wide angle edge state to a tele edge state, change of the aberration outside a shaft accompanying [ since the flexibility on aberration amendment increases and change of the lateral magnification accompanying change of the lens position state of each lens group becomes small ] change of a lens position state — good — an amendment — things become possible and it is easy to attain high variable power-ization

[0004] However, with the conventional multi-group zoom lens, since it is necessary to give aberration amendment for each [ which constitutes a zoom lens ] lens group of every, the lens number of sheets which needs several or more lenses in each lens group, therefore constitutes a zoom lens according to the increase in a moving-lens group will increase. Not only manufacture is cheaply impossible, but the thickness at the time of storing in the main part of a camera will become large, and the miniaturization of the main part of a camera will be difficult, so that lens number of sheets increases.

[0005] In the former, there is comparatively little lens number of sheets, and the right positive/negative 3 group type is known as a zoom lens suitable for the miniaturization. As a such right positive/negative 3 group type zoom lens, it is indicated by JP,6-67093,A, JP,6-230284,A or JP,8-101341,A, etc., for example. Now, in respect of portability, a lens shutter formula camera is excellent compared with a single-lens reflex camera, and it is excellent in portability, so that it is small and lightweight. Furthermore, as for a lens shutter formula camera, attaining the miniaturization of a taking lens, since taking lenses are a main part of a camera and one leads to a miniaturization and lightweight-ization of the main part of a camera.

[0006] Moreover, in order to raise the portability at the time of intact, in case the taking lens for lens shutter formula cameras stores a taking lens in the main part of a camera, it is stored in the state where the interval of \*\*\*\*\* lens groups serves as the minimum. Generally, although the

one where the field angle included in a wide angle edge state in a zoom lens is narrower can realize high variable power-ization easily, at this time, the lens overall length in a tele edge state cannot become large to screen diagonal length, and the miniaturization of a camera cannot be attained. Therefore, in order to have realized small variable power optical system with a high variable power ratio, to include a wide angle region more was desired.

[0007]

[Problem(s) to be Solved by the Invention] However, with the zoom lens of the conventional right positive/negative 3 group type indicated by JP,6-67093,A mentioned above, JP,6-230284,A, and JP,8-101341,A, when it has passed through the position where the axial outdoor daylight bunch separated from the optical axis in the 3rd lens group considerably in the wide angle edge state and is going to include a wide angle region more, a back focus becomes extremely short, the diameter of a lens becomes very large as a result, and there is a trouble that the miniaturization of a lens system cannot be attained.

[0008] Although it made it more effective for the miniaturization of a lens system for the range of focal distance change to shift to a short focus side, maintaining a predetermined variable power ratio, a wide angle region could not be included, namely, since the range of focal distance change was not able to be shifted to a short focus side, the miniaturization of a lens system was inadequate [ when raising the portability of the main part of a camera as mentioned above, the miniaturization of a lens system was important, and / the conventional right positive/negative 3 group type ].

[0009] both [ thus, ] JP,6-67093,A JP,6-230284,A and JP,8-101341,A -- although -- although high variable power-ization was attained by few lens composition number of sheets, wide-angle-izing was not enough, and coexistence-izing with a miniaturization and a raise in variable power was difficult, maintaining a predetermined variable power ratio The purpose of this invention is offering the variable power optical system which solved the above trouble and fitted a miniaturization and low-cost-ization.

[0010]

[Means for Solving the Problem] The 1st lens group in which the variable power optical system concerning this invention has right refractive power in order [ side / body ], It is constituted by the 3rd lens group which has the 2nd lens group which has right refractive power, and negative refractive power. So that the interval of the aforementioned 1st lens group and the aforementioned 2nd lens group may increase and the interval of the aforementioned 2nd lens group and the aforementioned 3rd lens group may decrease, in case a lens position state changes from a wide angle edge state to a tele edge state All lens groups move to a body side, and the aforementioned 2nd lens group consists of only a negative-lens component which turned the concave surface to the body side, and a positive-lens component which turned the convex to the image side, and aims at the target achievement by satisfying the following conditional expression (1).

[0011]

[Equation 2]

$$(1) 0.9 < f_1 / (f_w \cdot f_t)^{1/2} < 2.0$$

[0012]

[Embodiments of the Invention] First, the composition of the variable power optical system concerning this invention is explained. As the variable power optical system concerning this invention is shown in drawing 2 , from a body side in order It has 3rd lens group G3 of the 1st lens group G1 of right refractive power, the 2nd lens group G2 of right refractive power, and negative refractive power. In case a lens position state changes from a wide angle edge state to a tele edge state, the interval of the 1st lens group G1 and the 2nd lens group G2 increases, and all three lens groups move to a body side so that the interval of the 2nd lens group G2 and 3rd lens group G3 may decrease.

[0013] In this invention, aperture-diaphragm S moves independently one-wise with the 2nd lens group, in case it is desirable to be arranged between the 1st lens group and the 3rd lens group and a lens position state changes. Next, the function of each lens group is explained. A dilation

ratio (that is, lateral magnification) becomes large as the 3rd lens group of negative refractive power expands the photographic subject image formed of the 1st lens group and the 2nd lens group and a lens position state changes from a wide angle edge state to a tele edge state.

[0014] The position which passes the 3rd lens group of an axial outdoor daylight bunch by shortening a back focus in the state of a wide angle edge separates from an optical axis. Can amend shaft top aberration and the aberration outside a shaft independently, and a back focus follows for becoming large (that is, a lens position state changing from a wide angle edge state to a tele edge state). The position which passes the 3rd lens group of an axial outdoor daylight bunch can approach an optical axis, therefore change of the aberration outside a shaft accompanying variable power can be suppressed easily.

[0015] However, since the problem of the diameter of a lens becoming large is also generated in order to become or to secure the predetermined amount of ambient lights that it is easy to produce the problem on which the shadow of the dust of the 3rd lens group which adhered on the lens side by the side of an image most is reflected on a film plane, if a back focus is extremely shortened too much in a wide angle edge state, considering as a suitable back focus is desirable.

[0016] As for the 2nd lens group of right refractive power, the aperture diaphragm is arranged in near and the position which passes the 2nd lens group of the shaft top flux of light and an axial outdoor daylight bunch has few differences. Therefore, shaft top aberration is mainly amended. here -- an aperture diaphragm -- the body side of the 2nd lens group -- or when an image side is adjoined and it has arranged, it is desirable to make the lens side most distant from the aperture diaphragm into the aspheric surface In order that the axial outdoor daylight bunch which passes through the lens side most distant from the aperture diaphragm in this 2nd lens group may separate from an optical axis in a wide angle edge state, in the aspheric surface, then shaft top aberration and the aberration outside a shaft, this lens side can be amended independently and a good image formation performance is obtained [ side ] by few lens number of sheets.

[0017] Moreover, in this invention, in order to secure sufficient back focus in a wide angle edge state, the 2nd lens group consists of a negative-part part group (negative-lens component which turned the concave surface to the body side) arranged at a body side, and a positive-part part group (positive-lens component which turned the convex to the image side) arranged at an image side. Now, as for the 1st lens group of right refractive power, it is desirable to constitute from a negative-part part group arranged at a body side and a positive-part part group arranged at an image side. thereby -- refractive-power arrangement with the whole optical system -- un-- the positive distortion aberration which tends to be generated in a wide angle edge state since it is symmetrical -- good -- an amendment -- things are made Although negative spherical aberration can also be amended good by considering as such composition, lightweightizing and simple composition-ization can be attained by constituting a negative-part part group and a positive-part part group from one lens especially, respectively.

[0018] Especially in this invention, it is desirable to arrange an aperture diaphragm to the body side of the 2nd lens group. JP,6-67093,A mentioned to the conventional technology -- setting -- the [ the image side of the 2nd lens group, or ], although the aperture diaphragm is arranged between the negative-part part groups and positive-part part groups which constitute 2 lens groups In the thing of this JP,6-67093,A The aberration outside a shaft generated in a wide angle edge state to an amendment sake good in the meniscus configuration where the negative lens of the 2nd lens group arranged most at a body side turned the convex to the body side Or it is considering as the shape of both concaves that turned the concave surface with loose curvature to the body side, and in such a configuration, the transpiration for attaining wide angle-ization more is weak, and sufficient back focus is not obtained.

[0019] Therefore, when having arranged the aperture diaphragm to the body side of the 2nd lens group and the negative lens of the 2nd lens group arranged most at a body side turns a concave surface strong against a body side, generating of the aberration outside a shaft is suppressed, and sufficient back focus is obtained also in a wide angle edge state. In this invention, it is more desirable than a wide angle edge state to drive an aperture diaphragm with movement magnitude independent of the 2nd lens group to a tele edge state. In this case, the height which passes the

2nd lens group of an axial outdoor daylight bunch according to a lens position state comes to change, and change of the aberration outside a shaft accompanying change of a lens position state can be amended good.

[0020] It is desirable to make it move so that an aperture diaphragm may separate from the 2nd lens group as an aperture diaphragm is arranged near the 2nd lens group in the state of a wide angle edge and a lens position state changes to a tele edge state especially. This is because it will become difficult for the axial outdoor daylight bunch which passes the 2nd lens group to separate from an optical axis extremely, and to perform good aberration amendment by few lens number of sheets if an aperture diaphragm is separated from the 2nd lens group in order that the flux of light with a big field angle may carry out incidence in a wide angle edge state.

[0021] Hereafter, each conditional expression is explained. Conditional expression (1) is conditional expression which specifies the focal distance of the 1st lens group. When it exceeds the upper limit of conditional expression (1), it will become weaker about the astiction by the 1st lens group, and shortening of the lens overall length in a tele edge will be difficult. On the contrary, when less than the lower limit of conditional expression (1), the astiction by the 1st lens group becomes strong, the axial outdoor daylight bunch which passes the 1st lens group separates from an optical axis in a tele edge state, and since the flux of light passes the periphery section of each lens which constitutes the 1st lens group, in a tele edge state, generating of comatic aberration to an axial outdoor daylight bunch cannot be suppressed.

[0022] In addition, in order to attain a miniaturization more, it is desirable to set the upper limit of conditional expression (1) to 1.9. By the way, although shortening of a lens overall length is directly connected with the miniaturization of the main part of a camera, the looking-far ratio is known as a standard of a miniaturization. When the looking-far ratio B sets a focal distance to  $f$  and it sets a lens overall length to tangent line, it is the amount defined by  $B = \text{tangent line}/f$  and it is shown that it is so small that it is less than 1.

[0023] In this invention, in order to obtain high performance in a tele edge state and to attain a miniaturization, it is desirable to satisfy conditional expression (1) and to satisfy the following conditional expression (5).

(5) In order to obtain a good image formation performance also in  $0.8 < TL_t/f_t < 1$  and a wide angle edge state, it is desirable to satisfy the following conditional expression (6) simultaneously with conditional expression (1) and (5).

(6)  $TL_w/f_w > 1.2$  conditional expression (5) is conditional expression which specifies the looking-far ratio in a tele edge state.

[0024] If it exceeds the upper limit of conditional expression (5) and a looking-far ratio becomes large, enlargement of a lens system will be produced and it will be contrary to the main point of this invention. On the contrary, since the refractive-power arrangement in a tele edge state becomes extremely un-symmetrical when less than the lower limit of conditional expression (5), positive distortion aberration cannot be amended good. Conditional expression (6) is conditional expression which specifies the looking-far ratio in a wide angle edge state.

[0025] Since the incident angle of the axial outdoor daylight bunch which carries out incidence to optical system is large in the state of a wide angle edge, it is easy to separate an axial outdoor daylight bunch from an optical axis, therefore is easy to generate the aberration outside a shaft. For this reason, in order to attain a miniaturization and highly-efficient-izing of the diameter of a lens, it is important to bring an axial outdoor daylight bunch close to an optical axis, and it is important to ease the non-symmetric property of refractive power. In a wide angle edge state, the 1st lens group and the 2nd lens group which have right refractive power are unifying, and refractive-power arrangement of the whole optical system turns into arrangement of positive/negative. In order to ease the non-symmetric property of refractive power, by arranging the lens group which has negative refractive power in the body approach of optical system, it is desirable to bring refractive-power arrangement close to the symmetrical type of negative positive/negative, and a lens overall length becomes large to a focal distance at this time.

[0026] Therefore, when less than the lower limit of conditional expression (6), in a wide angle edge state, positive distortion aberration cannot be amended good, and highly efficient-ization

cannot be attained. In this invention, in order to attain miniaturization of the diameter of a lens, and shortening of the lens overall length in a tele edge, it is desirable to satisfy the following conditional expression (2).

(2)  $0.6 < (T_{Lt} - T_{Lw}) / (f_t - f_w) < 0.9$  conditional expression (2) is conditional expression which specifies the change of a lens overall length to change of the focal distance at the time of a lens position state changing.

[0027] When it exceeds the upper limit of conditional expression (2), enlargement of the lens overall length in shortening of the back focus in \*\* wide angle edge state or \*\* tele edge state is caused. \*\* a case — predetermined — in order to cause enlargement of the diameter of a lens for maintaining the amount of ambient lights, in any case, lead to enlargement of a lens system, and it is contrary to the intention of this application. On the contrary, since the performance degradation according to the eccentricity of a lens group to the time of manufacture although the miniaturization of a lens system can be attained when less than a lower limit, since the refractive power of each lens group becomes strong is remarkable and a high process tolerance is needed, it is contrary to low-cost-ization.

[0028] In this invention, in order to attain the miniaturization of the diameter of a lens of the 3rd lens group, it is desirable to satisfy the following conditional expression (3).

(3)  $w > \beta_{3t} 1.40$  conditional expression (3) is conditional expression which specifies the operating scale factor of the 3rd lens group in a wide angle edge state.

[0029] When less than the lower limit of conditional expression (3), the back focus in a wide angle edge state becomes short, the axial outdoor daylight bunch which passes the 3rd lens group will separate from an optical axis, and the diameter of a lens will be enlarged. In addition, when lateral-magnification  $\beta_{3w}$  in a wide angle edge state becomes large, there is an inclination which becomes large according to it also lateral-magnification  $\beta_{3t}$  in a tele edge state. The image surface transfer coefficient of the 3rd lens group in a tele edge state [0030]

[Equation 3]

$$(= \beta_{3t}^2 - 1)$$

[0031] Since it increases with regards to the square of the lateral magnification of a \*\*\* 3 lens group, if the lateral magnification of the 3rd lens group in a wide angle edge state is raised maintaining a predetermined variable power ratio, the image surface transfer coefficient of the 3rd lens group which can be set extremely will become extremely large, and the problem from which change (as opposed to a predetermined image surface position) of the image surface position by stopping accuracy arises, and predetermined optical-character ability is not obtained will arise.

[0032] It is desirable to set the upper limit of conditional expression (3) to 1.6 in this invention, from the above thing, for obtaining predetermined optical-character ability. By the way, it is known from the 1st lens group most arranged among each lens group which constitutes optical system at a body side in case a lens position state changes from a wide angle edge state to a tele edge state that the lateral magnification of the lens group arranged at an image side will change, and it is in the inclination for change of many aberration generated with change of a lens position state to become large, so that the variation of lateral magnification is large.

[0033] Therefore, in order to attain a high variable power ratio by the few lens group, it is important that the change of lateral magnification according to change of a lens position state loses an extremely large lens group. In order to realize highly efficient-ization, maintaining a predetermined variable power ratio since it is fundamentally generated by change of the interval of \*\*\*\*\* lens groups, as for the change of lateral magnification according to change of a lens position state, it is desirable to satisfy the following conditional expression (4).

(4)  $0.5 < (D1 T - D1W) / (D2 W - D2T) < 2$  conditional expression (4) is conditional expression which specifies the ratio of the variation by change of the lens position state of the 2nd adjustable interval formed of the 1st adjustable interval and the 2nd lens group which are formed of the 1st lens group and the 2nd lens group, and the 3rd lens group.

[0034] When it exceeds the upper limit of conditional expression (4), change of the lateral magnification of the 2nd lens group accompanying change of a lens position state becomes large,

and cannot amend change of the aberration outside a shaft generated in the 2nd lens group good. On the contrary, when less than the lower limit of conditional expression (4), change of the lateral magnification of the 3rd lens group accompanying change of a lens position state becomes large, and cannot amend change of the aberration outside a shaft generated in the 3rd lens group good.

[0035] In order to attain highly efficient-ization more especially, it is desirable to set a upper limit to 1.85 and to set a lower limit to 0.75. In this invention, since optical system is constituted from few lens number of sheets, it is desirable to introduce the aspheric surface. It is desirable to constitute the 3rd lens group from a positive lens and a negative lens in an amendment effectively for the aberration outside a shaft in a wide-angle edge state, and to aspheric-ize the lens side by the side of the body of a positive lens especially, and it is desirable to aspheric-ize the lens side which is most distant from the aperture diaphragm of the 2nd lens group to an amendment effectively in the shaft top aberration generated in the 2nd lens group and the aberration outside a shaft.

[0036] Now, in case a photograph is taken, in order that blurring which tends to be generated with a high variable power zoom lens may prevent failure by image Bure of a cause according to another viewpoint in this invention The inside of the lens group which combines with a lens system the Bure detection system and driving means which detect Bure, and constitutes a lens system, Bure who makes the whole or its part a decentered-lens group, was made to do eccentricity of the one lens group, detected Bure by the Bure detection system, and was detected — an amendment — eccentricity of the decentered-lens group is carried out by driving means like, and an image is shifted — making — image Bure — an amendment — it is possible to consider as vibrationproofing optical system by things

[0037]

[Example] Below, each example by this invention is explained. Drawing 1 shows refractive-power distribution of the variable power optical system by each example of this invention. In order, it is constituted from a body side by the 1st lens group G1 of right refractive power, the 2nd lens group G2 of right refractive power, and three lens groups of 3rd lens group G3 of negative refractive power. In case a lens position state changes from a wide angle edge state to a tele edge state, the interval of the 1st lens group G1 and the 2nd lens group G2 increases, and all lens groups move to a body side so that the interval of the 2nd lens group G2 and 3rd lens group G3 may decrease.

[0038] Moreover, the aspheric surface is expressed with the following formulas in each example.

[0039]

[Equation 4]

$$x = c y^2 / \{1 + (1 - \kappa c^2 y^2)^{1/2}\} + C_4 y^4 + C_6 y^6 + \dots$$

なお、yは光軸からの高さ、xはサグ量、cは曲率、 $\kappa$ は円錐定数、 $C_4$ 、 $C_6$ 、…は非球面係数である。

[0040] [1st example] drawing 2 shows the lens block diagram by the 1st example of this invention. The 1st lens group G1 consists of a negative lens L11 of a meniscus configuration which turned the convex to the body side, and a positive lens L12 of a meniscus configuration which turned the convex to the body side. The 2nd lens group G2 consists of the negative lenses L21 and biconvex lenses L22 of a meniscus configuration which turned the concave surface to the body side, and 3rd lens group G3 consists of a positive lens L31 of a meniscus configuration which turned the convex to the image side, and a negative lens L32 of a meniscus configuration which turned the concave surface to the body side. Aperture-diaphragm S moves in one with the 2nd lens group G2, in case it is arranged at the body side of a negative lens L21 and a lens position state changes.

[0041] In the 1st example, a short-distance focus can be performed by moving the 2nd lens group G2 in the direction of an optical axis. The value of the item of the 1st example in this invention is hung up over following Tables 1-5. A focal distance and FNO express the f number, f in the item table of an example expresses 2omega of field angles, and a refractive index is a

value over d line (lambda= 587.6nm).

[0042]

[Table 1]

f	30.90	~	57.01	~	78.11
FNO	4.38	~	7.29	~	9.35
2ω	67.26	~	40.24	~	30.24°
面番号	曲率半径	面間隔	屈折率	アッペ数	
1	19.6599	1.000	1.84666	23.83	
2	15.2372	1.000	1.0		
3	13.1462	2.500	1.51680	64.20	
4	34.8791	(D4)	1.0		
5	0.0000	2.500	1.0	(開口絞り)	
6	-6.7673	1.625	1.83500	42.97	
7	-8.5917	0.250	1.0		
8	119.2871	4.375	1.51680	64.20	
9	-10.8925	(D9)	1.0		
10	-31.2500	2.500	1.68893	31.16	
11	-26.0457	2.875	1.0		
12	-11.8149	1.250	1.79668	45.37	
13	-78.6331	(Bf)	1.0		

The 9th page and the 10th page are the aspheric surfaces, and an aspheric surface coefficient is as being shown below.

[0043]

[Table 2]

[第 9 面]

$$\kappa = 1.0000$$

$$C_4 = +1.13475 \times 10^{-4}$$

$$C_6 = -5.28843 \times 10^{-7}$$

$$C_8 = +1.63890 \times 10^{-8}$$

$$C_{10} = -2.67187 \times 10^{-11}$$

[第 10 面]

$$\kappa = 1.0000$$

$$C_4 = +7.42810 \times 10^{-5}$$

$$C_6 = +5.21535 \times 10^{-8}$$

$$C_8 = -9.40908 \times 10^{-10}$$

$$C_{10} = +2.05393 \times 10^{-11}$$

[0044]

[Table 3]

[Adjustable interval table]

f 30.9009 57.0144 78.1125D4 2.8545 9.3372 12.7996D9 9.8589 4.0023 1.8750Bf 7.9227 27.4954

42.0802 [0045]

[Table 4]

[Movement magnitude delta 2 of o'clock of the photography scale-factor=1/30 time 2nd lens group G2]

f 30.9009 57.0144 78.1125D0 929.3189 1704.9695 2333.0302delta2 0.5098 0.3329 0.2706 (in addition, movement magnitude by the side of a body is made positive)

[0046]

[Table 5]

[条件式対応値]

$f_1 = +73.1582$

$\beta_{3w} = 1.478$

- (1)  $f_1 / (f_w \cdot f_t)^{1/2} = 1.489$
- (2)  $(T_{Lt} - T_{Lw}) / (f_t - f_w) = 0.765$
- (3)  $\beta_{3w} = 1.478$
- (4)  $(D_{1T} - D_{1W}) / (D_{2W} - D_{2T}) = 1.246$
- (5)  $T_{Lt} / f_t = 0.981$
- (6)  $T_{Lw} / f_w = 1.311$

[0047] Drawing 3 or drawing 8 shows many aberration views of the 1st example of this invention, drawing 3 or drawing 5 expresses many aberration views in a wide angle edge, a middle focal distance state, and the infinite distance focus state in a tele edge, respectively, and drawing 6 or drawing 8 expresses many aberration views in a wide angle edge, a middle focal distance state, and the photography scale-factor-1/30 time state in a tele edge, respectively. In each aberration view of drawing 3 or drawing 8, the solid line in a spherical-aberration view shows spherical aberration, a dotted line shows sign condition, y shows image quantity, the solid line in an astigmatic view shows the sagittal image surface, and a dashed line shows a meridional image surface. a comatic-aberration view — the image quantity  $y = 0, 5.4, 10.8$ , and  $15$ . — expressing the comatic aberration of 12 and 21.6, A expresses an incident angle and H expresses body quantity

[0048] It is clear from each aberration view this example's to have the image formation performance which many aberration was amended good and was excellent.

[2nd example] drawing 9 shows the lens block diagram by the 2nd example of this invention. The 1st lens group G1 consists of junction positive lenses L1 of the negative lens of a meniscus configuration which turned the convex to the body side, and the positive lens of a meniscus configuration which turned the convex to the body side. The 2nd lens group G2 consists of the negative lenses L21 and biconvex lenses L22 of a meniscus configuration which turned the concave surface to the body side, and 3rd lens group G3 consists of a positive lens L31 of a meniscus configuration which turned the convex to the image side, and a negative lens L32 of a meniscus configuration which turned the concave surface to the body side. In case it is arranged at the body side of a negative lens L21 and a lens position state changes, aperture-diaphragm S reaches 1st lens group G1, and moves apart from the 2nd lens group G2.

[0049] In this 2nd example, a short-distance focus can be performed by moving the 2nd lens group G2 in the direction of an optical axis. The value of the item of the 2nd example in this invention is hung up over following Tables 6-10. A focal distance and FNO express the f number, f in the item table of an example expresses 2omega of field angles, and a refractive index is a value over d line ( $\lambda = 587.6\text{nm}$ ).

[0050]

[Table 6]

f	32.18	~	52.40	~	82.48
FNO	4.58	~	6.69	~	9.56
2ω	64.38	~	43.38	~	28.78°
面番号	曲率半径	面間隔	屈折率	アッペ数	
1	17.3882	1.375	1.84666	23.83	
2	14.2536	3.750	1.48749	70.45	
3	31.8383	(D3)	1.0		
4	0.0000	(D4)	1.0	(開口絞り)	
5	-8.4420	1.250	1.80420	46.51	
6	-12.5107	1.250	1.0		
7	41.3109	3.750	1.51680	64.20	
8	-10.3111	(D8)	1.0		
9	-31.2500	2.500	1.68893	31.16	
10	-22.8590	3.000	1.0		
11	-11.5072	1.500	1.76684	46.80	
12	-106.4021	(Bf)	1.0		

An octavus side and the 9th page are the aspheric surfaces, and an aspheric surface coefficient is as being shown below.

[0051]

[Table 7]

[第8面]

$$\begin{aligned}\kappa &= 1.0000 \\ C_4 &= +1.40810 \times 10^{-4} \\ C_6 &= +8.76052 \times 10^{-7} \\ C_8 &= -2.45514 \times 10^{-8} \\ C_{10} &= +4.74648 \times 10^{-10}\end{aligned}$$

[第9面]

$$\begin{aligned}\kappa &= 1.0000 \\ C_4 &= +6.86490 \times 10^{-5} \\ C_6 &= +2.71725 \times 10^{-7} \\ C_8 &= -4.81737 \times 10^{-9} \\ C_{10} &= +4.10814 \times 10^{-11}\end{aligned}$$

[0052]

[Table 8]

[Adjustable interval table]

f 32.1810 52.4033 82.4846D3 2.1250 10.7122 17.2421D4 2.2295 2.5000 2.5000D8 10.2339 5.2523  
1.8750Bf 7.8722 21.7151 41.2521 [0053]

[Table 9]

[Movement magnitude delta 2 of o'clock of the photography scale-factor=1/30 time 2nd lens group G2]

f 32.1810 52.4033 82.4846D0 970.0358 1565.6369 2458.0212delta2 0.5363 0.4040 0.3030 (in addition, movement magnitude by the side of a body is made positive)

[0054]

[Table 10]

[条件式対応値]

$f_1 = +94.4053$

$\beta_{3w} = 1.4507$

(1)  $f_1 / (f_w \cdot f_t)^{1/2} = 1.832$

(2)  $(T_{Lt} - T_{Lw}) / (f_t - f_w) = 0.803$

(3)  $\beta_{3w} = 1.451$

(4)  $(D_{1T} - D_{1W}) / (D_{2W} - D_{2T}) = 1.809$

(5)  $T_{Lt} / f_t = 0.985$

(6)  $T_{Lw} / f_w = 1.269$

[0055] Drawing 10 or drawing 15 shows many aberration views of the 2nd example of this invention, drawing 10 or drawing 12 expresses many aberration views in a wide angle edge, a middle focal distance state, and the infinite distance focus state in a tele edge, respectively, and drawing 13 or drawing 15 expresses many aberration views in a wide angle edge, a middle focal distance state, and the photography scale-factor=1/30 time state in a tele edge, respectively. In each aberration view of drawing 10 or drawing 15, the solid line in a spherical-aberration view shows spherical aberration, a dotted line shows sign condition, y shows image quantity, the solid line in an astigmatic view shows the sagittal image surface, and a dashed line shows a meridional image surface. a comatic-aberration view -- the image quantity  $y = 0, 5.4, 10.8$ , and  $15$ . -- expressing the comatic aberration of 12 and 21.6, A expresses an incident angle and H expresses body quantity

[0056] It is clear from each aberration view this example's to have the image formation performance which many aberration was amended good and was excellent.

[3rd example] drawing 16 shows the lens block diagram by the 3rd example of this invention. The 1st lens group G1 consists of a negative lens L11 of a meniscus configuration which turned the concave surface to the body side, and a positive lens L12 of both the convex configuration. The 2nd lens group G2 consists of the negative lenses L21 of a meniscus configuration and the positive lenses L22 of both the convex configuration which turned the concave surface to the body side, and 3rd lens group G3 consists of a positive lens L31 of a meniscus configuration which turned the convex to the image side, and a negative lens L32 of a meniscus configuration which turned the concave surface to the body side. An aperture diaphragm moves in one with the 2nd lens group G2, in case it is arranged at the body side of a negative lens L21 and a lens position state changes.

[0057] In the 3rd example, a short-distance focus can be performed by moving the 2nd lens group G2 in the direction of an optical axis. The value of the item of the 3rd example in this invention is hung up over following Tables 11-15. A focal distance and FNO express the f number, f in the item table of an example expresses 2omega of field angles, and a refractive index is a value over d line ( $\lambda = 587.6\text{nm}$ ).

[0058]

[Table 11]

f	30.90	~	55.94	~	78.75
FNO	4.34	~	7.22	~	9.34
2ω	67.42	~	41.06	~	30.04°
面番号	曲率半径	面間隔	屈折率	アッペ数	
1	-31.0540	1.000	1.84666	23.83	
2	-139.8968	0.375	1.0		
3	21.7397	2.500	1.48749	70.45	
4	-52.9497	(D4)	1.0		
5	0.0000	2.500	1.0	(開口絞り)	
6	-8.5930	1.625	1.80420	46.51	
7	-12.3730	0.250	1.0		
8	126.5221	4.375	1.51680	64.20	
9	-10.6761	(D9)	1.0		
10	-31.2500	2.375	1.68893	31.16	
11	-27.2213	3.125	1.0		
12	-11.8908	1.250	1.76684	46.80	
13	-231.6048	(Bf)	1.0		

The 9th page and the 10th page are the aspheric surfaces, and an aspheric surface coefficient is as being shown below.

[0059]

[Table 12]

[第9面]

$$\kappa = 1.0000$$

$$C_4 = +1.24560 \times 10^{-4}$$

$$C_6 = -1.12260 \times 10^{-6}$$

$$C_8 = +7.08167 \times 10^{-8}$$

$$C_{10} = -1.34486 \times 10^{-9}$$

[第10面]

$$\kappa = 1.0000$$

$$C_4 = +6.79153 \times 10^{-5}$$

$$C_6 = -2.92853 \times 10^{-7}$$

$$C_8 = +7.08167 \times 10^{-9}$$

$$C_{10} = -6.67544 \times 10^{-12}$$

[0060]

[Table 13]

[Adjustable interval table]

f 30.9003 55.9441 78.7499D4 2.2500 7.0157 10.7871D9 10.9892 4.5518 1.8750Bf 7.8438 28.1679

44.5921 [0061]

[Table 14]

[Movement magnitude delta 2 of o'clock of the photography scale-factor=1/30 time 2nd lens group G2]

f 30.9003 55.9441 78.7499D0 929.9937 1676.3029 2355.8007delta2 0.5657 0.3660 0.2974 (in addition, movement magnitude by the side of a body is made positive)

[0062]

[Table 15]

[条件式対応値]

$f_1 = +58.1194$

$\beta_{3w} = 1.4448$

(1)  $f_1 / (f_w \cdot f_t)^{1/2} = 1.178$

(2)  $(T_{Lt} - T_{Lw}) / (f_t - f_w) = 0.756$

(3)  $\beta_{3w} = 1.445$

(4)  $(D_{1T} - D_{1W}) / (D_{2W} - D_{2T}) = 0.937$

(5)  $T_{Lt} / f_t = 0.973$

(6)  $T_{Lw} / f_w = 1.309$

[0063] Drawing 17 or drawing 22 shows many aberration views of the 3rd example of this invention, drawing 17 or drawing 19 expresses many aberration views in a wide angle edge, a middle focal distance state, and the infinite distance focus state in a tele edge, respectively, and drawing 20 or drawing 22 expresses many aberration views in a wide angle edge, a middle focal distance state, and the photography scale-factor-1/30 time state in a tele edge, respectively. In each aberration view of drawing 17 or drawing 22, the solid line in a spherical-aberration view shows spherical aberration, a dotted line shows sign condition, y shows image quantity, the solid line in an astigmatic view shows the sagittal image surface, and a dashed line shows a meridional image surface. a comatic-aberration view — the image quantity  $y = 0, 5.4, 10.8$ , and  $15$ . — expressing the comatic aberration of 12 and 21.6, A expresses an incident angle and H expresses body quantity

[0064] It is clear from each aberration view this example's to have the image formation performance which many aberration was amended good and was excellent.

[4th example] drawing 23 shows the lens block diagram by the 4th example of this invention. The 1st lens group G1 consists of a both concave-like negative lens L11 and a positive lens L12 of both the convex configuration. The 2nd lens group G2 consists of a negative lens L21 of a meniscus configuration which turned the concave surface to the body side, and a positive lens L22 of a meniscus configuration which turned the convex to the image side. 3rd lens group G3 consists of a positive lens L31 of a meniscus configuration which turned the convex to the image side, and a negative lens L32 of a meniscus configuration which turned the concave surface to the body side. Aperture-diaphragm S moves in one with the 2nd lens group G2, in case it is arranged at the body side of a negative lens L21 and a lens position state changes.

[0065] In the 4th example, a short-distance focus can be performed by moving the 2nd lens group G2 in the direction of an optical axis. The value of the item of the 4th example in this invention is hung up over following Tables 16-20. A focal distance and FNO express the f number, f in the item table of an example expresses 2omega of field angles, and a refractive index is a value over d line ( $\lambda = 587.6\text{nm}$ ).

[0066]

[Table 16]

f	30.90	~	56.02	~	78.75
FNO	4.43	~	7.24	~	9.32
2ω	67.06	~	40.68	~	29.84°
面番号	曲率半径	面間隔	屈折率	アッペ数	
1	-124.1213	1.000	1.75520	27.53	
2	98.5796	0.375	1.0		
3	19.9046	1.750	1.58913	61.24	
4	-547.4991	(D4)	1.0		
5	0.0000	2.500	1.0	(開口絞り)	
6	-8.0380	1.625	1.80454	39.61	
7	-11.0146	0.250	1.0		
8	-136.1576	5.000	1.62041	60.35	
9	-11.4675	(D9)	1.0		
10	-31.2500	2.375	1.68893	31.16	
11	-25.8365	2.750	1.0		
12	-12.7789	1.250	1.79668	45.37	
13	-121.1517	(Bf)	1.0		

The 9th page and the 10th page are the aspheric surfaces, and an aspheric surface coefficient is as being shown below.

[0067]

[Table 17]

[第9面]

$$\kappa = 0.8171$$

$$C_4 = +8.06707 \times 10^{-5}$$

$$C_6 = -1.10605 \times 10^{-6}$$

$$C_8 = +4.83834 \times 10^{-8}$$

$$C_{10} = -7.38936 \times 10^{-10}$$

[第10面]

$$\kappa = 0.0090$$

$$C_4 = +6.20237 \times 10^{-5}$$

$$C_6 = -1.16831 \times 10^{-7}$$

$$C_8 = +7.67159 \times 10^{-10}$$

$$C_{10} = +3.95016 \times 10^{-12}$$

[0068]

[Table 18]

[Adjustable interval table]

f 30.9001 56.0238 78.7484D4 1.7500 7.2672 11.0000D9 11.5327 5.3356 2.7500Bf 7.9525 27.3167

43.0421 [0069]

[Table 19]

[Movement magnitude delta 2 of o'clock of the photography scale-factor=1/30 time 2nd lens group G2]

f 30.9001 56.0238 78.7484D0 930.2685 1677.8917 2354.6307delta2 0.5504 0.3660 0.2988 (in addition, movement magnitude by the side of a body is made positive)

[0070]

[Table 20]

[条件式対応値]

$f_1 = +58.3170$

$\beta_{3w} = 1.4615$

(1)  $f_1 / (f_w \cdot f_t)^{1/2} = 1.206$

(2)  $(T_{L_t} - T_{L_w}) / (f_t - f_w) = 0.743$

(3)  $\beta_{3w} = 1.462$

(4)  $(D_{1T} - D_{1W}) / (D_{2W} - D_{2T}) = 1.053$

(5)  $T_{L_t} / f_t = 0.961$

(6)  $T_{L_w} / f_w = 1.298$

[0071] Drawing 24 or drawing 29 shows many aberration views of the 4th example of this invention, drawing 24 or drawing 26 expresses many aberration views in a wide angle edge, a middle focal distance state, and the infinite distance focus state in a tele edge, respectively, and drawing 27 or drawing 29 expresses many aberration views in a wide angle edge, a middle focal distance state, and the photography scale-factor-1/30 time state in a tele edge, respectively. In each aberration view of drawing 24 or drawing 29, the solid line in a spherical-aberration view shows spherical aberration, a dotted line shows sign condition, y shows image quantity, the solid line in an astigmatic view shows the sagittal image surface, and a dashed line shows a meridional image surface. a comatic-aberration view — the image quantity y= 0, 5.4, 10.8, and 15. — expressing the comatic aberration of 12 and 21.6, A expresses an incident angle and H expresses body quantity

[0072] It is clear from each aberration view this example's to have the image formation performance which many aberration was amended good and was excellent.

[0073]

[Effect of the Invention] According to this invention, the small variable power optical system in which a raise in variable power is possible is realizable.

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[Translation done.]

(19)日本国特許庁 (J P)

(12) 公開特許公報 (A)

(11)特許出願公開番号

特開平10-90600

(43)公開日 平成10年(1998)4月10日

(51)Int.Cl.<sup>6</sup>

G 0 2 B 15/20  
13/18

識別記号

F I

G 0 2 B 15/20  
13/18

(21)出願番号

特願平8-241472

(22)出願日

平成8年(1996)9月12日

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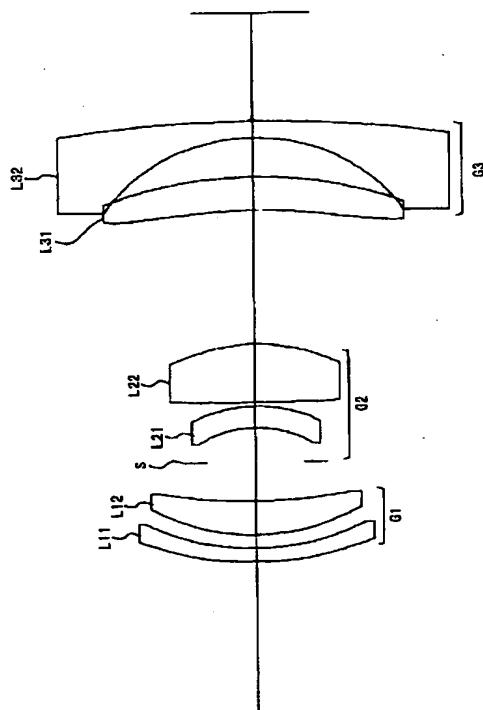
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(54)【発明の名称】 変倍光学系

(57)【要約】

【課題】小型化と低コスト化に適した変倍光学系を提供する。

【解決手段】物体側より順に、正屈折力を有する第1レンズ群G1、正屈折力を有する第2レンズ群G2および負屈折力を有する第3レンズ群G3により構成され、広角端状態より望遠端状態までレンズ位置状態が変化する際に、前記第1レンズ群と前記第2レンズ群との間隔が増大し、前記第2レンズ群と前記第3レンズ群との間隔が減少するように、すべてのレンズ群が物体側へ移動し、前記第2レンズ群は物体側へ凹面を向けた負レンズ成分と像側へ凸面を向けた正レンズ成分だけで構成され、第1レンズ群の好適な焦点距離の範囲を規定したものである。



## 【特許請求の範囲】

【請求項1】物体側より順に、正屈折力を有する第1レンズ群、正屈折力を有する第2レンズ群および負屈折力を有する第3レンズ群により構成され、広角端状態より望遠端状態までレンズ位置状態が変化する際に、前記第1レンズ群と前記第2レンズ群との間隔が増大し、前記第2レンズ群と前記第3レンズ群との間隔が減少するように、すべてのレンズ群が物体側へ移動して、

前記第2レンズ群は物体側へ凹面を向けた負レンズ成分と像側へ凸面を向けた正レンズ成分だけで構成され、以下の条件式(1)を満足することを特徴とする変倍光学系。

## 【数1】

$$(1) 0.9 < f_1 / (f_w \cdot f_t)^{1/2} < 2.0$$

但し、

$f_1$ ：前記第1レンズ群の焦点距離

$f_w$ ：前記変倍光学系の広角端状態における全系での焦点距離

$f_t$ ：前記変倍光学系の望遠端状態における全系での焦点距離

である。

【請求項2】前記第2レンズ群に隣接して配置された開口絞りをさらに有し、

レンズ位置状態が変化する際に、前記開口絞りは前記第2レンズ群と一緒に移動することを特徴とする請求項1記載の変倍光学系。

【請求項3】前記第2レンズ群中のレンズ面のうち、前記開口絞りからもっとも離れて位置するレンズ面は非球面であることを特徴とする請求項2記載の変倍光学系。

【請求項4】前記開口絞りは、前記第1レンズ群と前記第2レンズ群との間に配置されることを特徴とする請求項2または3記載の変倍光学系。

【請求項5】前記第1レンズ群は、負レンズ成分とその像側に配置される正レンズ成分だけで構成されることを特徴とする請求項1または4記載の変倍光学系。

【請求項6】以下の条件式(2)を満足することを特徴とする請求項1または5記載の変倍光学系。

$$(2) 0.6 < (T_L t - T_L w) / (f_t - f_w) < 0.9$$

但し、

$T_L t$ ：望遠端状態におけるレンズ全長

$T_L w$ ：広角端状態におけるレンズ全長

である。

【請求項7】以下の条件式(3)を満足することを特徴とする請求項6記載の変倍光学系。

$$(3) \beta_{3w} > 1.40$$

但し、

$\beta_{3w}$ ：広角端状態における前記第3レンズ群の横倍率である

【請求項8】前記第1レンズ群と前記第2レンズ群との間に配置される開口絞りをさらに有し、広角端状態より望遠端状態までレンズ位置状態が変化する際に、前記開口絞りは第2レンズ群とは異なる移動量比で移動することを特徴とする請求項1記載の変倍光学系。

【請求項9】以下の条件式(4)を満足することを特徴とする請求項1または8記載の変倍光学系。

$$(4) 0.5 < (D1T - D1W) / (D2W - D2T) < 2$$

但し、

$D1T$ ：望遠端状態における前記第1レンズ群のもっとも像側の面より前記第2レンズ群のもっとも物体側の面までの光軸に沿った長さ

$D1W$ ：広角端状態における前記第1レンズ群のもっとも像側の面より前記第2レンズ群のもっとも物体側の面までの光軸に沿った長さ

$D2T$ ：望遠端状態における前記第2レンズ群のもっとも像側の面より前記第3レンズ群のもっとも物体側の面までの光軸に沿った長さ

$D2W$ ：広角端状態における前記第2レンズ群のもっとも像側の面より前記第3レンズ群のもっとも物体側の面までの光軸に沿った長さ

である。

## 【発明の詳細な説明】

## 【0001】

【発明の属する技術分野】本発明は、小型の変倍光学系に関し、特に広角端状態において65度を超える画角を包括する変倍光学系に関する。

## 【0002】

【従来の技術】最近のレンズシャッター式カメラ用の撮影レンズにおいては、ズームレンズが一般的となり、変倍比が2倍を超える高変倍ズームレンズを備えたカメラが主流となりつつある。従来より、正レンズ群と負レンズ群とで構成される2群ズームレンズが知られている。この2群ズームレンズでは、変倍比を高めようすると、レンズ位置状態の変化に伴う軸外収差の変動を良好に補正することが難しくなる問題や、あるいは、広角端状態(焦点距離が最も短い状態)より望遠端状態(焦点距離が最も長い状態)までレンズ位置状態が変化する際の移動量が大きくなつて、鏡筒構造の複雑化を招く等の問題が起こつてしまつていて。

【0003】また、多群ズームレンズは、3つ以上の可動レンズ群を有しており、広角端状態より望遠端状態まで各レンズ群の移動する移動軌跡(ズーム軌道)に選択の自由度が生じるため、収差補正上の自由度が増加し、また、各レンズ群のレンズ位置状態の変化に伴う横倍率の変化が小さくなるため、レンズ位置状態の変化に伴う軸外収差の変動を良好に補正することが可能となり、高変倍化を達成し易い。

【0004】しかしながら、従来の多群ズームレンズで

は、ズームレンズを構成する各レンズ群ごとに収差補正を施す必要があるため、各レンズ群において数枚以上のレンズを必要とし、従って、可動レンズ群の増加に従い、ズームレンズを構成するレンズ枚数が増えてしまう。レンズ枚数が増えるほど、安価に製造ができないだけでなく、カメラ本体内に格納した際の厚みが大きくなり、カメラ本体の小型化が困難となってしまう。

【0005】従来において、比較的レンズ枚数が少なく、且つ小型化に適したズームレンズとして、正正負3群タイプが知られている。このような正正負3群タイプのズームレンズとしては、例えば、特開平6-67093号公報や、特開平6-230284号公報、あるいは特開平8-101341号公報等に開示されている。さて、レンズシャッター式カメラは携帯性の点で一眼レフカメラに比べて優れ、また小型・軽量であるほど携帯性に優れている。さらにレンズシャッター式カメラは、撮影レンズがカメラ本体と一体であるため、撮影レンズの小型化を図ることがカメラ本体の小型化・軽量化につながる。

【0006】また、レンズシャッター式カメラ用の撮影レンズは、未使用時の携帯性を高めるために、撮影レンズをカメラ本体内に格納する際に、隣合うレンズ群同士の間隔が最小となるような状態で格納している。一般的に、ズームレンズにおいては、広角端状態において包括する画角が狭い方が、容易に高変倍化を実現できるが、このときには望遠端状態におけるレンズ全長が画面対角長に対して大きくなり、カメラの小型化を図ることができない。従って、小型で且つ変倍比が高い変倍光学系を実現するには、より広角域を包括することが望まれた。

#### 【0007】

【発明が解決しようとする課題】しかしながら、上述した特開平6-67093号公報、特開平6-230284号公報、特開平8-101341号公報に開示される従来の正正負3群タイプのズームレンズでは、広角端状態において軸外光束が第3レンズ群における光軸からかなり離れた位置を通過しており、より広角域を包括しようとすると、バックフォーカスが極端に短くなり、結果的にレンズ径が非常に大きくなってしまい、レンズ系の小型化が図れない問題点がある。

【0008】前述した通り、カメラ本体の携帯性を高める上で、レンズ系の小型化が肝要であり、所定の変倍比を維持しながら、焦点距離変化の範囲を短焦点側へ移行させる方がレンズ系の小型化に効果的であるが、従来の正正負3群タイプでは広角域を包括できない、即ち焦点距離変化の範囲を短焦点側へ移行できないために、レンズ系の小型化が不十分であった。

【0009】このように特開平6-67093号公報、特開平6-230284号公報、特開平8-101341号公報の何れもが、少ないレンズ構成枚数で高変倍化を達成しているが、広角化が十分でなく、所定の変倍比

を維持しながら小型化と高変倍化との両立化が困難だった。本発明の目的は、以上の問題点を解決し、小型化と低コスト化に適した変倍光学系を提供することである。

#### 【0010】

【課題を解決するための手段】本発明にかかる変倍光学系は、物体側より順に、正屈折力を有する第1レンズ群、正屈折力を有する第2レンズ群および負屈折力を有する第3レンズ群により構成され、広角端状態より望遠端状態までレンズ位置状態が変化する際に、前記第1レンズ群と前記第2レンズ群との間隔が増大し、前記第2レンズ群と前記第3レンズ群との間隔が減少するよう、すべてのレンズ群が物体側へ移動し、前記第2レンズ群は物体側へ凹面を向けた負レンズ成分と像側へ凸面を向けた正レンズ成分だけで構成され、以下の条件式

(1) を満足することにより目的の達成を図るものである。

#### 【0011】

#### 【数2】

$$(1) 0.9 < f_1 / (f_w \cdot f_t)^{1/2} < 2.0$$

#### 【0012】

【発明の実施の形態】まず、本発明にかかる変倍光学系の構成について説明する。本発明にかかる変倍光学系は、例えば図2に示す如く、物体側より順に、正屈折力の第1レンズ群G1、正屈折力の第2レンズ群G2および負屈折力の第3レンズ群G3を有し、広角端状態より望遠端状態までレンズ位置状態が変化する際に、第1レンズ群G1と第2レンズ群G2との間隔が増大し、第2レンズ群G2と第3レンズ群G3との間隔が減少するよう、3つのレンズ群すべてが物体側へ移動するものである。

【0013】本発明において、開口絞りSは第1レンズ群と第3レンズ群との間に配置されることが好ましく、レンズ位置状態が変化する際に、第2レンズ群と一体的か、もしくは独立に移動する。次に、各レンズ群の機能について説明する。負屈折力の第3レンズ群は、第1レンズ群と第2レンズ群により形成される被写体像を拡大し、広角端状態から望遠端状態へとレンズ位置状態が変化するに従い、拡大率(つまり横倍率)が大きくなる。

【0014】広角端状態では、バックフォーカスを短くすることにより軸外光束の第3レンズ群を通過する位置が光軸から離れて、軸上収差と軸外収差とを独立に補正でき、バックフォーカスが大きくなる(つまり広角端状態から望遠端状態へとレンズ位置状態が変化する)に従い、軸外光束の第3レンズ群を通過する位置が光軸に近づき、従って、変倍に伴う軸外収差の変動を容易に抑えることができる。

【0015】但し、広角端状態においてバックフォーカスを極端に短くしすぎると、第3レンズ群の最も像側のレンズ面上に付着したゴミの影がフィルム面上に写り込

む問題が生じやすくなったり、あるいは、所定の周辺光量を確保するには、レンズ径が大きくなってしまう等の問題も発生するため、適切なバックフォーカスとすることが望ましい。

【0016】正屈折力の第2レンズ群は、開口絞りが近くに配置されており、軸上光束と軸外光束の第2レンズ群を通過する位置に差が少ない。従って、主に軸上収差の補正を行っている。ここで、開口絞りを第2レンズ群の物体側や、あるいは像側に隣接して配置した場合、開口絞りから最も離れたレンズ面を非球面とすることが望ましい。この第2レンズ群中の開口絞りから最も離れたレンズ面を通過する軸外光束が広角端状態において光軸から離れるため、このレンズ面を非球面とすれば、軸上収差と軸外収差とを独立に補正でき、少ないレンズ枚数で良好な結像性能が得られる。

【0017】また、本発明においては、広角端状態において十分なバックフォーカスを確保するために、第2レンズ群を物体側に配置される負部分群（物体側へ凹面を向けた負レンズ成分）と像側に配置される正部分群（像側へ凸面を向けた正レンズ成分）とで構成している。さて、正屈折力の第1レンズ群は、物体側に配置される負部分群と像側に配置される正部分群で構成することが好ましい。これにより、光学系全体での屈折力配置が不対称であるために、広角端状態において発生しがちな正の歪曲収差を良好に補正することができる。このような構成とすることにより、負の球面収差も良好に補正可能であるが、特に負部分群と正部分群とをそれぞれ1枚のレンズで構成することにより、軽量化や簡易構成化が図れる。

【0018】本発明においては、特に開口絞りを第2レンズ群の物体側に配置することが望ましい。従来技術に挙げた特開平6-67093号公報においては、第2レンズ群の像側か、あるいは第2レンズ群を構成する負部分群と正部分群との間に開口絞りを配置しているが、この特開平6-67093号公報のものでは、広角端状態において発生する軸外収差を良好に補正するために、第2レンズ群の最も物体側に配置される負レンズが物体側に凸面を向けたメニスカス形状あるいは、物体側に曲率の緩い凹面を向けた両凹形状としており、このような形状では、より広角化を図るための発散作用が弱く、十分なバックフォーカスが得られない。

【0019】従って、開口絞りを第2レンズ群の物体側に配置すれば、第2レンズ群の最も物体側に配置される負レンズが物体側に強い凹面を向けた際にも軸外収差の発生が抑えられ、広角端状態においても十分なバックフォーカスが得られる。本発明において、広角端状態より望遠端状態まで開口絞りを第2レンズ群とは独立の移動量で駆動することが好ましい。この場合、レンズ位置状態により軸外光束の第2レンズ群を通過する高さが変化するようになって、レンズ位置状態の変化に伴う軸

外収差の変動を良好に補正できる。

【0020】特に、広角端状態では開口絞りが第2レンズ群の近傍に配置され、望遠端状態へレンズ位置状態が変化するに従い、開口絞りが第2レンズ群から離れるよう移動させることが望ましい。これは、広角端状態においては画角の大きな光束が入射するため、開口絞りを第2レンズ群から離すと、第2レンズ群を通過する軸外光束が極端に光軸から離れてしまい、少ないレンズ枚数で良好な収差補正を行うことが困難になるからである。

【0021】以下、各条件式について説明する。条件式(1)は、第1レンズ群の焦点距離を規定する条件式である。条件式(1)の上限値を上回った場合、第1レンズ群による収斂作用が弱まり、望遠端におけるレンズ全長の短縮化が困難となってしまう。逆に、条件式(1)の下限値を下回った場合、第1レンズ群による収斂作用が強まり、第1レンズ群を通過する軸外光束が望遠端状態において光軸から離れて、第1レンズ群を構成する各レンズの周縁部を光束が通過するため、望遠端状態において軸外光束に対するコマ収差の発生を抑えられない。

【0022】なお、より小型化を図るには、条件式

(1)の上限値を1.9とすることが望ましい。ところで、レンズ全長の短縮化はカメラ本体の小型化に直接的に結びつくが、小型化の目安として望遠比が知られている。望遠比Bは、焦点距離をf、レンズ全長をTLとするとき、

$$B = TL / f$$

で定義される量であり、1を下回るほど小型であることを示す。

【0023】本発明において、望遠端状態において高性能を得て且つ小型化を図るために、条件式(1)を満足し、且つ以下の条件式(5)を満足することが好ましい。

$$(5) 0.8 < TL / f < 1$$

また、広角端状態においても良好な結像性能を得るには、以下の条件式(6)も条件式(1)および(5)と同時に満足することが望ましい。

$$(6) TL / f > 1.2$$

条件式(5)は、望遠端状態における望遠比を規定する条件式である。

【0024】条件式(5)の上限値を上回って、望遠比が大きくなると、レンズ系の大型化を生じてしまい、本発明の主旨に反する。逆に、条件式(5)の下限値を下回った場合、望遠端状態における屈折力配置が極端に不対称となるので、正の歪曲収差を良好に補正できない。条件式(6)は、広角端状態における望遠比を規定する条件式である。

【0025】広角端状態では、光学系に入射する軸外光束の入射角が大きいため、軸外光束が光軸から離れやすく、従って、軸外収差が発生しやすい。このため、レンズ径の小型化と高性能化を達成するには、軸外光束を光

軸に近づけることが肝要であり、屈折力の不対称性を緩和することが重要である。広角端状態においては、正屈折力を有する第1レンズ群と第2レンズ群とが一体化しており、光学系全体の屈折力配置は正負の配置となる。屈折力の不対称性を緩和するには、光学系の物体寄りに負屈折力を有するレンズ群を配置することにより、屈折力配置を負正負の対称型に近づけることが望ましく、このときにはレンズ全長が焦点距離に対して大きくなる。

【0026】従って、条件式(6)の下限値を下回った場合、広角端状態において正の歪曲収差を良好に補正できず、高性能化が図れない。本発明においては、レンズ径の小型化と望遠端におけるレンズ全長の短縮化を図るために、以下の条件式(2)を満足することが望ましい。

$$(2) 0.6 < (T_L t - T_L w) / (f_t - f_w) < 0.9$$

条件式(2)は、レンズ位置状態が変化した際の焦点距離の変化に対するレンズ全長の変化を規定する条件式である。

【0027】条件式(2)の上限値を上回った場合、①広角端状態におけるバックフォーカスの短縮化か、あるいは、②望遠端状態におけるレンズ全長の大型化を引き起こす。①の場合、所定の周辺光量を維持するにはレンズ径の大型化を引き起こすため、何れの場合もレンズ系の大型化につながり、本願の意図に反する。逆に、下限値を下回った場合、レンズ系の小型化が図れるが、各レンズ群の屈折力が強まるので製造時にレンズ群の偏心による性能劣化が著しく、高い加工精度が必要となるので低コスト化に反する。

【0028】本発明においては、第3レンズ群のレンズ径の小型化を図るために、以下の条件式(3)を満足することが望ましい。

$$(3) \beta_{3w} > 1.40$$

条件式(3)は、広角端状態における第3レンズ群の使用倍率を規定する条件式である。

【0029】条件式(3)の下限値を下回った場合、広角端状態におけるバックフォーカスが短くなってしまい、第3レンズ群を通過する軸外光束が光軸から離れてレンズ径が大型化してしまう。なお、広角端状態における横倍率 $\beta_{3w}$ が大きくなると、望遠端状態における横倍率 $\beta_{3t}$ もそれに従い大きくなる傾向がある。望遠端状態における第3レンズ群の像面移動係数

【0030】

【数3】

$$( = \beta_{3t}^2 - 1 )$$

【0031】は第3レンズ群の横倍率の2乗に関係して増大するため、所定の変倍比を維持しながら広角端状態における第3レンズ群の横倍率を高めると、極端における第3レンズ群の像面移動係数が極端に大きくなり、停止精度による像面位置の変動(所定の像面位置に対する

る)が生じて所定の光学性能が得られない問題が生じてしまう。

【0032】以上のことから、本発明においては、所定の光学性能を得るには条件式(3)の上限値を1.6とすることが望ましい。ところで、広角端状態から望遠端状態までレンズ位置状態が変化する際に、光学系を構成する各レンズ群のうち、最も物体側に配置される第1レンズ群より像側に配置されるレンズ群の横倍率が変化することが知られており、横倍率の変化量が大きいほどレンズ位置状態の変化に伴って発生する諸収差の変動が大きくなる傾向にある。

【0033】従って、少ないレンズ群で高い変倍比を達成するには、レンズ位置状態の変化に従う横倍率の変化が極端に大きいレンズ群をなくすことが肝要である。レンズ位置状態の変化に従う横倍率の変化は、基本的に隣合うレンズ群同士の間隔の変化によって生じるため、所定の変倍比を維持しながら高性能化が実現するためには、以下の条件式(4)を満足することが好ましい。

$$(4) 0.5 < (D1T - D1W) / (D2W - D2T) < 2$$

条件式(4)は、第1レンズ群と第2レンズ群とにより形成される第1可変間隔と第2レンズ群と第3レンズ群とにより形成される第2可変間隔のレンズ位置状態の変化による変化量の比を規定する条件式である。

【0034】条件式(4)の上限値を上回った場合、レンズ位置状態の変化に伴う第2レンズ群の横倍率の変化が大きくなり、第2レンズ群において発生する軸外収差の変動を良好に補正できない。逆に、条件式(4)の下限値を下回った場合、レンズ位置状態の変化に伴う第3レンズ群の横倍率の変化が大きくなり、第3レンズ群において発生する軸外収差の変動を良好に補正できない。

【0035】特に、より高性能化を図るには、上限値を1.85とし、下限値を0.75とすることが望ましい。本発明においては、少ないレンズ枚数で光学系を構成するために、非球面を導入することが望ましい。特に、広角端状態における軸外収差を効果的に補正するには、第3レンズ群を正レンズと負レンズで構成し、正レンズの物体側のレンズ面を非球面化することが好ましく、第2レンズ群において発生する軸上収差と軸外収差とを効果的に補正するには、第2レンズ群の開口絞りからもっとも離れたレンズ面を非球面化することが望ましい。

【0036】さて、本発明における別の観点によれば、撮影を行う際に、高変倍ズームレンズで発生しがちな手ブレ等が原因の像ブレによる失敗を防ぐために、ブレを検出するブレ検出系と駆動手段とをレンズ系に組み合わせ、レンズ系を構成するレンズ群のうち、1つのレンズ群を全体か、あるいはその一部を偏心レンズ群として偏心させ、ブレをブレ検出系により検出し、検出されたブレを補正するように駆動手段により偏心レンズ群を偏心させ像をシフトさせて、像ブレを補正することで防振光

学系とすることが可能である。

【0037】

【実施例】以下に、本発明による各実施例について説明する。図1は、本発明の各実施例による変倍光学系の屈折力配分を示しており、物体側より順に、正屈折力の第1レンズ群G1、正屈折力の第2レンズ群G2および負屈折力の第3レンズ群G3の3つのレンズ群で構成され、広角端状態より望遠端状態までレンズ位置状態が変

$$x = c y^2 / \{1 + (1 - \kappa c^2 y^2)^{1/2}\} + C_4 y^4 + C_6 y^6 + \dots$$

なお、yは光軸からの高さ、xはサグ量、cは曲率、 $\kappa$ は円錐定数、 $C_4$ 、 $C_6$ 、…は非球面係数である。

【0040】【第1実施例】図2は、本発明の第1実施例によるレンズ構成図を示しており、第1レンズ群G1は物体側に凸面を向けたメニスカス形状の負レンズL1、物体側に凸面を向けたメニスカス形状の正レンズL1.2で構成され、第2レンズ群G2は物体側へ凹面を向けたメニスカス形状の負レンズL2.1と両凸レンズL2.2で構成され、第3レンズ群G3は像側へ凸面を向けたメニスカス形状の正レンズL3.1と物体側に凹面を向けたメニスカス形状の負レンズL3.2で構成される。開口絞りSは負レンズL2.1の物体側に配置され、レンズ位置状態が変化する際に、第2レンズ群G2と一体的に移動する。

【0041】第1実施例においては、第2レンズ群G2を光軸方向に移動させることにより、近距離合焦が行える。以下の表1～5に、本発明における第1実施例の諸元の値を掲げる。実施例の諸元表中のfは焦点距離、FNOはFナンバー、2ωは画角を表し、屈折率はd線( $\lambda = 587.6\text{nm}$ )に対する値である。

【0042】

【表1】

面番号	曲率半径	面間隔	屈折率	アッペ数
1	19.6599	1.000	1.84666	23.83
2	15.2372	1.000	1.0	
3	13.1462	2.500	1.51680	64.20
4	34.8791	(D4)	1.0	
5	0.0000	2.500	1.0	(開口絞り)
6	-6.7673	1.625	1.83500	42.97
7	-8.5917	0.250	1.0	
8	119.2871	4.375	1.51680	64.20
9	-10.8925	(D9)	1.0	
10	-31.2500	2.500	1.68893	31.16
11	-26.0457	2.875	1.0	
12	-11.8149	1.250	1.79668	45.37
13	-78.6331	(Bf)	1.0	

第9面と第10面は非球面であり、非球面係数は以下に

化する際に、第1レンズ群G1と第2レンズ群G2との間隔が増大し、第2レンズ群G2と第3レンズ群G3との間隔が減少するよう、すべてのレンズ群が物体側へ移動する。

【0038】また、各実施例において、非球面は以下の式で表される。

【0039】

【数4】

示す通りである。

【0043】

【表2】

【第9面】

$$\begin{aligned}\kappa &= 1.0000 \\ C_4 &= +1.13475 \times 10^{-4} \\ C_6 &= -5.28843 \times 10^{-7} \\ C_8 &= +1.63890 \times 10^{-8} \\ C_{10} &= -2.67187 \times 10^{-11}\end{aligned}$$

【第10面】

$$\begin{aligned}\kappa &= 1.0000 \\ C_4 &= +7.42810 \times 10^{-5} \\ C_6 &= +5.21535 \times 10^{-8} \\ C_8 &= -9.40908 \times 10^{-10} \\ C_{10} &= +2.05393 \times 10^{-11}\end{aligned}$$

【0044】

【表3】

【可変間隔表】

f	30.9009	57.0144	78.1125
D4	2.8545	9.3372	12.7996
D9	9.8589	4.0023	1.8750
Bf	7.9227	27.4954	42.0802

【0045】

【表4】

【撮影倍率-1/30倍時の第2レンズ群G2の移動量

δ2】

f	30.9009	57.0144	78.1125
D0	929.3189	1704.9695	2333.0302
δ2	0.5098	0.3329	0.2706

(なお、物体側への移動量を正とする)

【0046】

【表5】

## [条件式対応値]

$$f_1 = +73.1582$$

$$\beta_{3w} = 1.478$$

$$(1) f_1 / (f_w \cdot f_t)^{1/2} = 1.489$$

$$(2) (T_{Lt} - T_{Lw}) / (f_t - f_w) = 0.765$$

$$(3) \beta_{3w} = 1.478$$

$$(4) (D_{1T} - D_{1W}) / (D_{2W} - D_{2T}) = 1.246$$

$$(5) T_{Lt} / f_t = 0.981$$

$$(6) T_{Lw} / f_w = 1.311$$

【0047】図3乃至図8は本発明の第1実施例の諸収差図を示し、図3乃至図5はそれぞれ広角端、中間焦点距離状態、望遠端での無限遠合焦状態における諸収差図を表し、図6乃至図8はそれぞれ広角端、中間焦点距離状態、望遠端での撮影倍率-1/30倍状態における諸収差図を表す。図3乃至図8の各収差図において、球面収差図中の実線は球面収差、点線はサイン・コンディションを示し、yは像高を示し、非点収差図中の実線はサジタル像面、破線はメリディオナル像面を示す。コマ収差図は、像高y=0, 5.4, 10.8, 15.12, 21.6でのコマ収差を表し、Aは入射角、Hは物体高を表す。

【0048】各収差図から、本実施例は諸収差が良好に補正され、優れた結像性能を有していることは明らかである。

【第2実施例】図9は、本発明の第2実施例によるレンズ構成図を示しており、第1レンズ群G1は物体側に凸面を向けたメニスカス形状の負レンズと物体側に凸面を向けたメニスカス形状の正レンズとの接合正レンズL1で構成され、第2レンズ群G2は物体側へ凹面を向けたメニスカス形状の負レンズL21と両凸レンズL22で構成され、第3レンズ群G3は像側へ凸面を向けたメニスカス形状の正レンズL31と物体側に凹面を向けたメニスカス形状の負レンズL32で構成される。開口絞りSは負レンズL21の物体側に配置され、レンズ位置状態が変化する際に、第1レンズ群G1及び第2レンズ群G2とは別に移動する。

【0049】この第2実施例においては、第2レンズ群G2を光軸方向に移動させることにより、近距離合焦が行える。以下の表6～10に、本発明における第2実施例の諸元の値を掲げる。実施例の諸元表中のfは焦点距離、FNOはFナンバー、2ωは画角を表し、屈折率はd線(λ=587.6nm)に対する値である。

## 【0050】

## 【表6】

f	32.18	~	52.40	~	82.48
FNO	4.58	~	6.69	~	9.56
2ω	64.38	~	43.38	~	28.78°
面番号	曲率半径	面間隔	屈折率	アッペ数	
1	17.3882	1.375	1.84666	23.83	
2	14.2536	3.750	1.48749	70.45	
3	31.8383	(D3)	1.0		
4	0.0000	(D4)	1.0	(開口絞り)	
5	-8.4420	1.250	1.80420	46.51	
6	-12.5107	1.250	1.0		
7	41.3109	3.750	1.51680	64.20	
8	-10.3111	(D8)	1.0		
9	-31.2500	2.500	1.68893	31.16	
10	-22.8590	3.000	1.0		
11	-11.5072	1.500	1.76684	46.80	
12	-106.4021	(Bf)	1.0		

第8面と第9面は非球面であり、非球面係数は以下に示す通りである。

## 【0051】

## 【表7】

## [第8面]

$$\kappa = 1.0000$$

$$C_4 = +1.40810 \times 10^{-4}$$

$$C_6 = +8.76052 \times 10^{-7}$$

$$C_8 = -2.45514 \times 10^{-8}$$

$$C_{10} = +4.74648 \times 10^{-10}$$

## [第9面]

$$\kappa = 1.0000$$

$$C_4 = +6.86490 \times 10^{-5}$$

$$C_6 = +2.71725 \times 10^{-7}$$

$$C_8 = -4.81737 \times 10^{-9}$$

$$C_{10} = +4.10814 \times 10^{-11}$$

## 【0052】

## 【表8】

## [可変間隔表]

f	32.1810	52.4033	82.4846
D3	2.1250	10.7122	17.2421
D4	2.2295	2.5000	2.5000
D8	10.2339	5.2523	1.8750
Bf	7.8722	21.7151	41.2521

## 【0053】

## 【表9】

[撮影倍率-1/30倍時の第2レンズ群G2の移動量  
δ2]

f 32.1810 52.4033 82.4846  
D0 970.0358 1565.6369 2458.0212

δ2 0.5363 0.4040 0.3030

(なお、物体側への移動量を正とする)

【0054】

【表10】

[条件式対応値]

f1=+94.4053

β3w=1.4507

(1)  $f_1 / (f_w \cdot f_t)^{1/2} = 1.832$

(2)  $(T_{L_t} - T_{L_w}) / (f_t - f_w) = 0.803$

(3)  $\beta_{3w} = 1.451$

(4)  $(D_{1T} - D_{1W}) / (D_{2W} - D_{2T}) = 1.809$

(5)  $T_{L_t} / f_t = 0.985$

(6)  $T_{L_w} / f_w = 1.269$

【0055】図10乃至図15は本発明の第2実施例の諸収差図を示し、図10乃至図12はそれぞれ広角端、中間焦点距離状態、望遠端での無限遠合焦状態における諸収差図を表し、図13乃至図15はそれぞれ広角端、中間焦点距離状態、望遠端での撮影倍率-1/30倍状態における諸収差図を表す。図10乃至図15の各収差図において、球面収差図中の実線は球面収差、点線はサイン・コンディションを示し、yは像高を示し、非点収差図中の実線はサジタル像面、破線はメリディオナル像面を示す。コマ収差図は、像高y=0, 5, 4, 10, 8, 15, 12, 21, 6でのコマ収差を表し、Aは入射角、Hは物体高を表す。

【0056】各収差図から、本実施例は諸収差が良好に補正され、優れた結像性能を有していることは明らかである。

【第3実施例】図16は、本発明の第3実施例によるレンズ構成図を示しており、第1レンズ群G1は物体側に凹面を向けたメニスカス形状の負レンズL11、両凸形状の正レンズL12で構成され、第2レンズ群G2は物体側へ凹面を向けたメニスカス形状の負レンズL21と両凸形状の正レンズL22で構成され、第3レンズ群G3は像側へ凸面を向けたメニスカス形状の正レンズL31と物体側に凹面を向けたメニスカス形状の負レンズL32で構成される。開口絞りは負レンズL21の物体側に配置され、レンズ位置状態が変化する際に、第2レンズ群G2と一体的に移動する。

【0057】第3実施例においては、第2レンズ群G2を光軸方向に移動させることにより、近距離合焦が行える。以下の表11~15に、本発明における第3実施例の諸元の値を掲げる。実施例の諸元表中のfは焦点距離、FNOはFナンバー、2ωは画角を表し、屈折率はd線(λ=587.6nm)に対する値である。

【0058】

【表11】

f	30.90	~	55.94	~	78.75
FNO	4.34	~	7.22	~	9.34
2ω	67.42	~	41.06	~	30.04°
面番号	曲率半径	面間隔	屈折率	アッペ数	
1	-31.0540	1.000	1.84666	23.83	
2	-139.8968	0.375	1.0		
3	21.7397	2.500	1.48749	70.45	
4	-52.9497	(D4)	1.0		
5	0.0000	2.500	1.0	(開口絞り)	
6	-8.5930	1.625	1.80420	46.51	
7	-12.3730	0.250	1.0		
8	126.5221	4.375	1.51680	64.20	
9	-10.6761	(D9)	1.0		
10	-31.2500	2.375	1.68893	31.16	
11	-27.2213	3.125	1.0		
12	-11.8908	1.250	1.76684	46.80	
13	-231.6048	(Bf)	1.0		

第9面と第10面は非球面であり、非球面係数は以下に示す通りである。

【0059】

【表12】

【第9面】

$\kappa = 1.0000$

$C_4 = +1.24560 \times 10^{-4}$

$C_6 = -1.12260 \times 10^{-6}$

$C_8 = +7.08167 \times 10^{-8}$

$C_{10} = -1.34486 \times 10^{-9}$

【第10面】

$\kappa = 1.0000$

$C_4 = +6.79153 \times 10^{-5}$

$C_6 = -2.92853 \times 10^{-7}$

$C_8 = +7.08167 \times 10^{-9}$

$C_{10} = -6.67544 \times 10^{-12}$

【0060】

【表13】

【可変間隔表】

f	30.9003	55.9441	78.7499
D4	2.2500	7.0157	10.7871

D9 10.9892 4.5518 1.8750  
Bf 7.8438 28.1679 44.5921

【0061】

【表14】

[撮影倍率-1/30倍時の第2レンズ群G2の移動量

δ2]

[条件式対応値]

$$f_1 = +58.1194$$

$$\beta_{3w} = 1.4448$$

$$(1) f_1 / (f_w \cdot f_t)^{1/2} = 1.178$$

$$(2) (T_L t - T_L w) / (f_t - f_w) = 0.756$$

$$(3) \beta_{3w} = 1.445$$

$$(4) (D_1T - D_1W) / (D_2W - D_2T) = 0.937$$

$$(5) T_L t / f_t = 0.973$$

$$(6) T_L w / f_w = 1.309$$

【0063】図17乃至図22は本発明の第3実施例の諸収差図を示し、図17乃至図19はそれぞれ広角端、中間焦点距離状態、望遠端での無限遠合焦状態における諸収差図を表し、図20乃至図22はそれぞれ広角端、中間焦点距離状態、望遠端での撮影倍率-1/30倍状態における諸収差図を表す。図17乃至図22の各収差図において、球面収差図中の実線は球面収差、点線はサイン・コンディションを示し、yは像高を示し、非点収差図中の実線はサジタル像面、破線はメリディオナル像面を示す。コマ収差図は、像高y=0, 5, 4, 10, 8, 15, 12, 21, 6でのコマ収差を表し、Aは入射角、Hは物体高を表す。

【0064】各収差図から、本実施例は諸収差が良好に補正され、優れた結像性能を有していることは明らかである。

【第4実施例】図23は、本発明の第4実施例によるレンズ構成図を示しており、第1レンズ群G1は両凹形状の負レンズL11、両凸形状の正レンズL12で構成され、第2レンズ群G2は物体側へ凹面を向けたメニスカス形状の負レンズL21と像側に凸面を向けたメニスカス形状の正レンズL22で構成され、第3レンズ群G3は像側へ凸面を向けたメニスカス形状の正レンズL31と物体側に凹面を向けたメニスカス形状の負レンズL32で構成される。開口絞りSは負レンズL21の物体側に配置され、レンズ位置状態が変化する際に、第2レンズ群G2と一体的に移動する。

【0065】第4実施例においては、第2レンズ群G2を光軸方向に移動させることにより、近距離合焦が行える。以下の表16～20に、本発明における第4実施例の諸元の値を掲げる。実施例の諸元表中のfは焦点距離、FNOはFナンバー、2ωは画角を表し、屈折率はd線(λ=587.6nm)に対する値である。

【0066】

【表16】

f 30.9003 55.9441 78.7499

D0 929.9937 1676.3029 2355.8007

δ2 0.5657 0.3660 0.2974

(なお、物体側への移動量を正とする)

【0062】

【表15】

f 30.90 ~ 56.02 ~ 78.75

FNO 4.43 ~ 7.24 ~ 9.32

2ω 67.06 ~ 40.68 ~ 29.84°

面番号	曲率半径	面間隔	屈折率	アッペ数
-----	------	-----	-----	------

1	-124.1213	1.000	1.75520	27.53
---	-----------	-------	---------	-------

2	98.5796	0.375	1.0	
---	---------	-------	-----	--

3	19.9046	1.750	1.58913	61.24
---	---------	-------	---------	-------

4	-547.4991	(D4)	1.0	
---	-----------	------	-----	--

5	0.0000	2.500	1.0	(開口絞り)
---	--------	-------	-----	--------

6	-8.0380	1.625	1.80454	39.61
---	---------	-------	---------	-------

7	-11.0146	0.250	1.0	
---	----------	-------	-----	--

8	-136.1576	5.000	1.62041	60.35
---	-----------	-------	---------	-------

9	-11.4675	(D9)	1.0	
---	----------	------	-----	--

10	-31.2500	2.375	1.68893	31.16
----	----------	-------	---------	-------

11	-25.8365	2.750	1.0	
----	----------	-------	-----	--

12	-12.7789	1.250	1.79668	45.37
----	----------	-------	---------	-------

13	-121.1517	(Bf)	1.0	
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第9面と第10面は非球面であり、非球面係数は以下に示す通りである。

【0067】

【表17】

[第9面]

$$\kappa = 0.8171$$

$$C_4 = +8.06707 \times 10^{-5}$$

$$C_6 = -1.10605 \times 10^{-6}$$

$$C_8 = +4.83834 \times 10^{-8}$$

$$C_{10} = -7.38936 \times 10^{-10}$$

[第10面]

$$\kappa = 0.0090$$

$$C_4 = +6.20237 \times 10^{-5}$$

$$C_6 = -1.16831 \times 10^{-7}$$

$$C_8 = +7.67159 \times 10^{-10}$$

$$C_{10} = +3.95016 \times 10^{-12}$$

【0068】

【表18】

[可変間隔表]

f	30.9001	56.0238	78.7484
D4	1.7500	7.2672	11.0000
D9	11.5327	5.3356	2.7500
Bf	7.9525	27.3167	43.0421

【0069】

【表19】

[撮影倍率-1/30倍時の第2レンズ群G2の移動量

[条件式対応値]

$$f_1 = +58.3170$$

$$\beta_{3w} = 1.4615$$

$$(1) f_1 / (f_w \cdot f_t)^{1/2} = 1.206$$

$$(2) (T_L t - T_L w) / (f_t - f_w) = 0.743$$

$$(3) \beta_{3w} = 1.462$$

$$(4) (D_1 T - D_1 W) / (D_2 W - D_2 T) = 1.053$$

$$(5) T_L t / f_t = 0.961$$

$$(6) T_L w / f_w = 1.298$$

δ2]

f 30.9001 56.0238 78.7484

D0 930.2685 1677.8917 2354.6307

δ2 0.5504 0.3660 0.2988

(なお、物体側への移動量を正とする)

【0070】

【表20】

【0071】図24乃至図29は本発明の第4実施例の諸収差図を示し、図24乃至図26はそれぞれ広角端、中間焦点距離状態、望遠端での無限遠合焦状態における諸収差図を表し、図27乃至図29はそれぞれ広角端、中間焦点距離状態、望遠端での撮影倍率-1/30倍状態における諸収差図を表す。図24乃至図29の各収差図において、球面収差図中の実線は球面収差、点線はサイエン・コンディションを示し、yは像高を示し、非点収差図中の実線はサジタル像面、破線はメリディオナル像面を示す。コマ収差図は、像高y=0, 5.4, 10.8, 15.12, 21.6でのコマ収差を表し、Aは入射角、Hは物体高を表す。

【0072】各収差図から、本実施例は諸収差が良好に補正され、優れた結像性能を有していることは明らかである。

【0073】

【発明の効果】本発明によれば、小型で且つ高変倍化が可能な変倍光学系を実現できる。

【図面の簡単な説明】

【図1】本発明による変倍光学系の屈折力配置を示す概念図

【図2】第1実施例の構成を示すレンズ断面図

【図3】第1実施例の広角端での無限遠合焦状態の諸収差図

【図4】第1実施例の中間焦点距離状態での無限遠合焦状態の諸収差図

【図5】第1実施例の望遠端での無限遠合焦状態の諸収差図

【図6】第1実施例の広角端での撮影倍率-1/30倍の諸収差図

【図7】第1実施例の中間焦点距離状態での撮影倍率-1/30倍の諸収差図

【図8】第1実施例の望遠端での撮影倍率-1/30倍の諸収差図

【図9】第2実施例の構成を示すレンズ断面図

【図10】第2実施例の広角端での無限遠合焦状態の諸収差図

【図11】第2実施例の中間焦点距離状態での無限遠合焦状態の諸収差図

【図12】第2実施例の望遠端での無限遠合焦状態の諸収差図

【図13】第2実施例の広角端での撮影倍率-1/30倍の諸収差図

【図14】第2実施例の中間焦点距離状態での撮影倍率-1/30倍の諸収差図

【図15】第2実施例の望遠端での撮影倍率-1/30倍の諸収差図

【図16】第3実施例の構成を示すレンズ断面図

【図17】第3実施例の広角端での無限遠合焦状態の諸収差図

【図18】第3実施例の中間焦点距離状態での無限遠合焦状態の諸収差図

【図19】第3実施例の望遠端での無限遠合焦状態の諸収差図

【図20】第3実施例の広角端での撮影倍率-1/30倍の諸収差図

【図21】第3実施例の中間焦点距離状態での撮影倍率-1/30倍の諸収差図

【図22】第3実施例の望遠端での撮影倍率-1/30倍の諸収差図

【図23】第4実施例の構成を示すレンズ断面図

【図24】第4実施例の広角端での無限遠合焦状態の諸収差図

【図25】第4実施例の中間焦点距離状態での無限遠合焦状態の諸収差図

【図26】第4実施例の望遠端での無限遠合焦状態の諸収差図

【図27】第4実施例の広角端での撮影倍率-1/30倍の

## 諸収差図

【図28】第4実施例の中間焦点距離状態での撮影倍率-1/30倍の諸収差図

【図29】第4実施例の望遠端での撮影倍率-1/30倍の

## 諸収差図

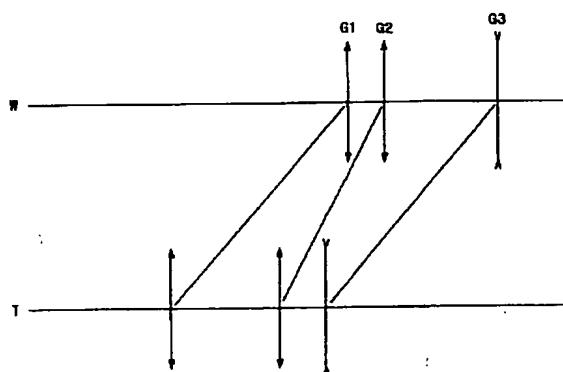
## 【符号の説明】

G1: 第1レンズ群、

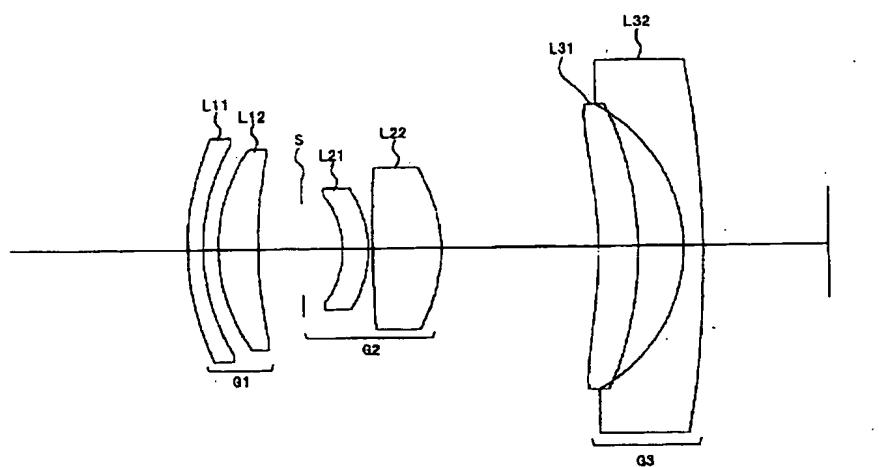
G2: 第2レンズ群、

G3: 第3レンズ群、

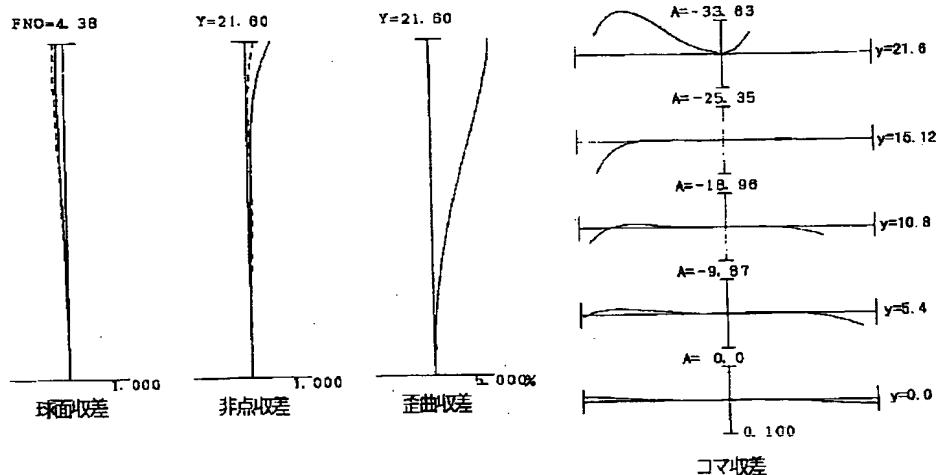
【図1】



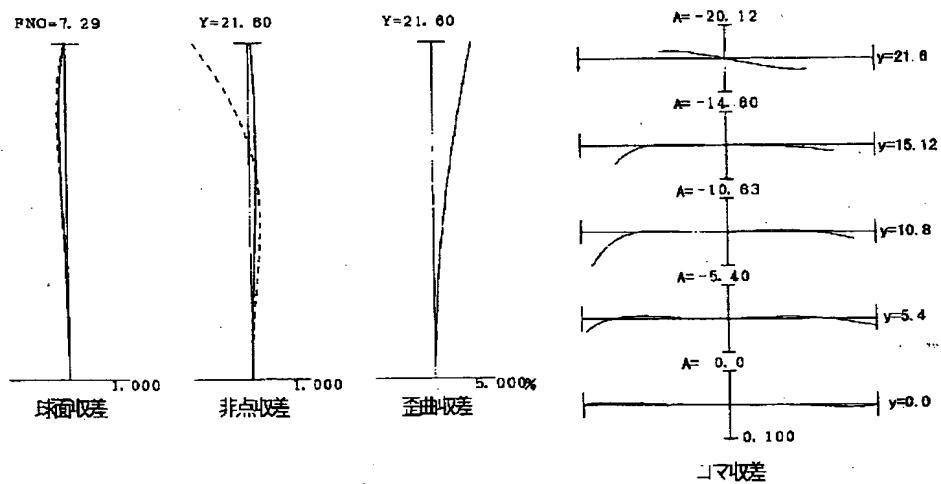
【図2】



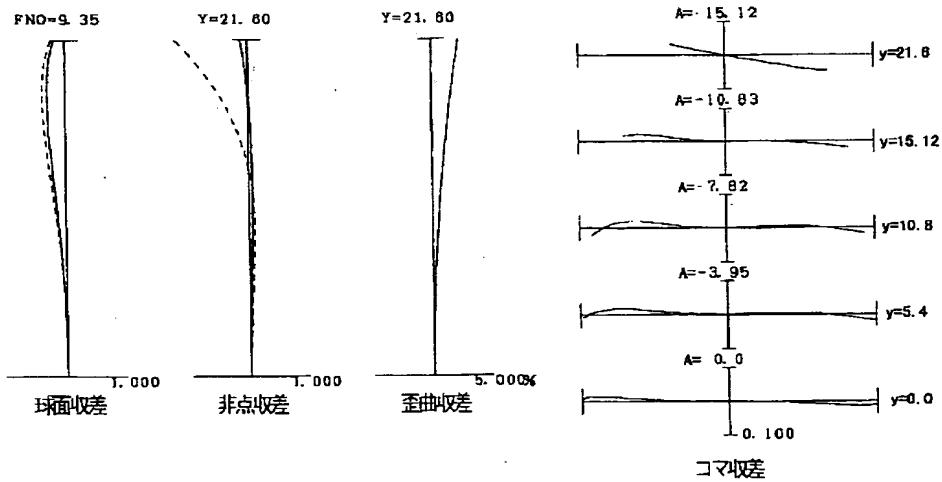
【図3】



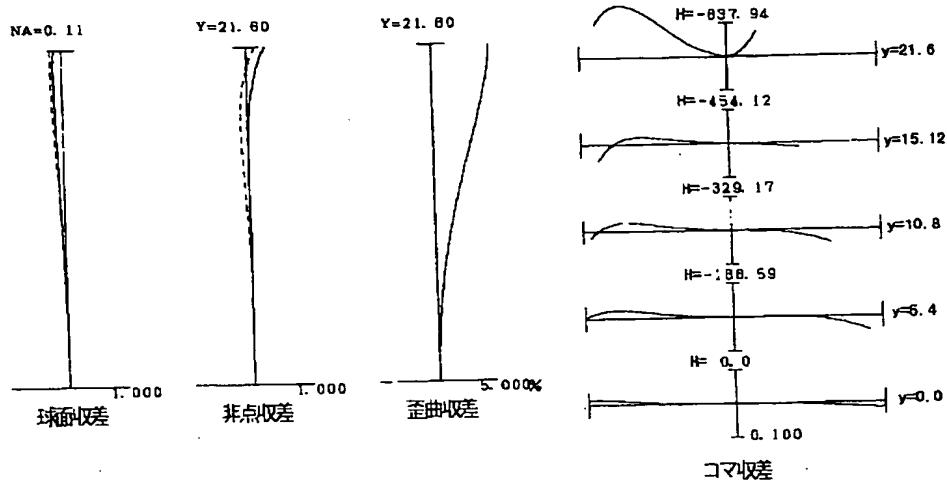
【図4】



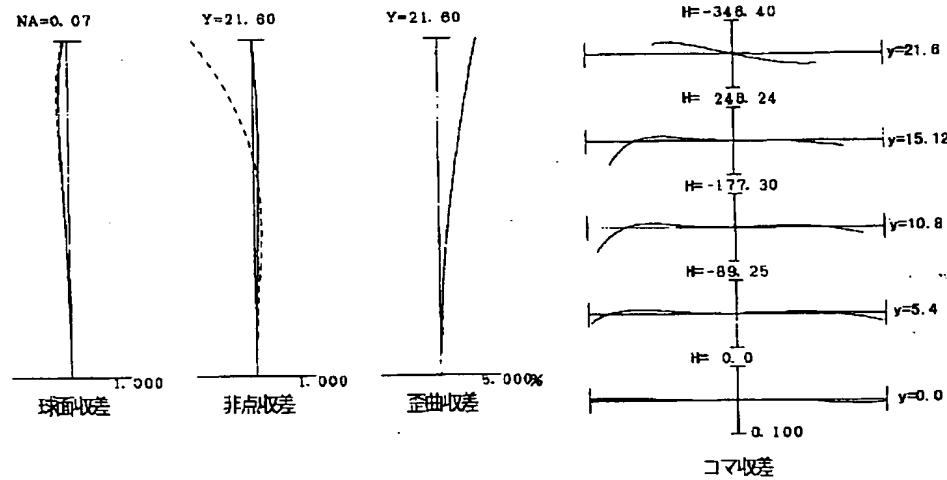
【図5】



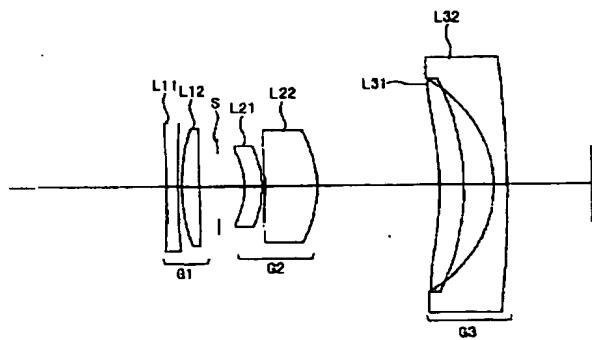
【図6】



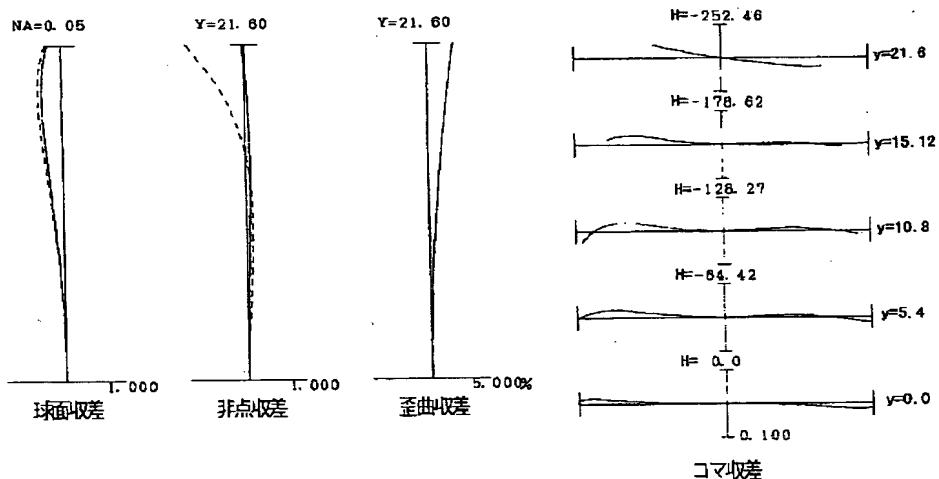
【図7】



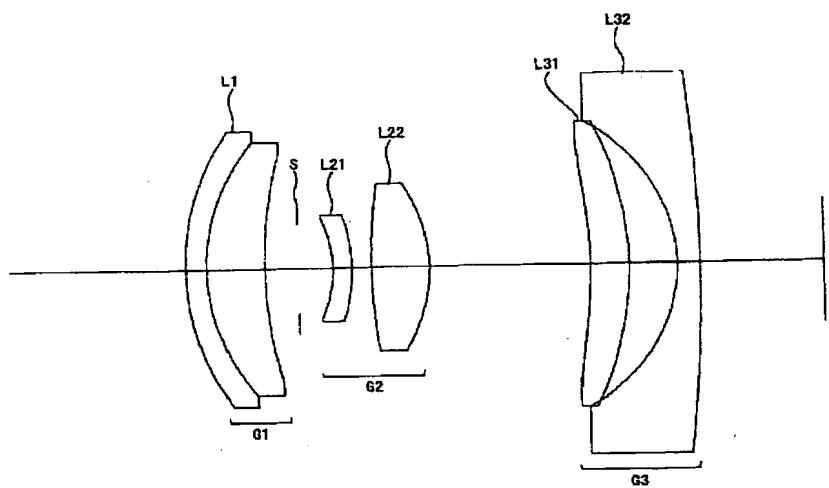
【図23】



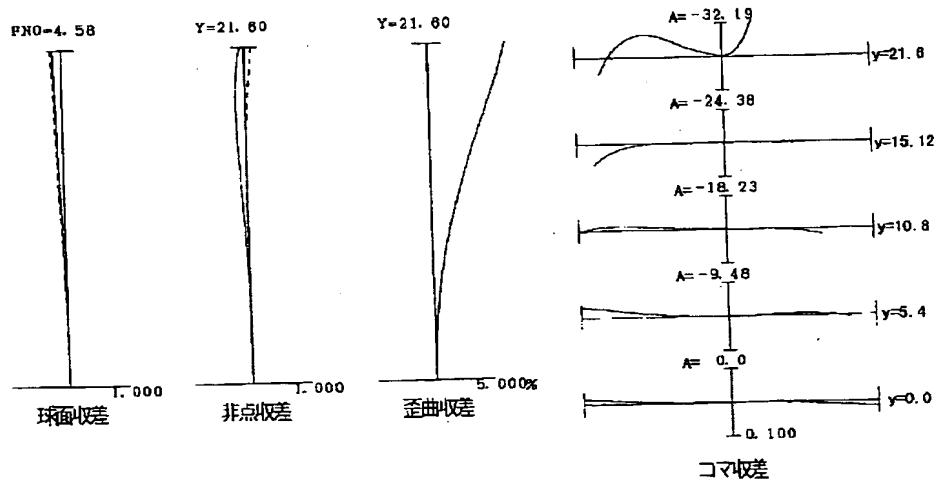
【図8】



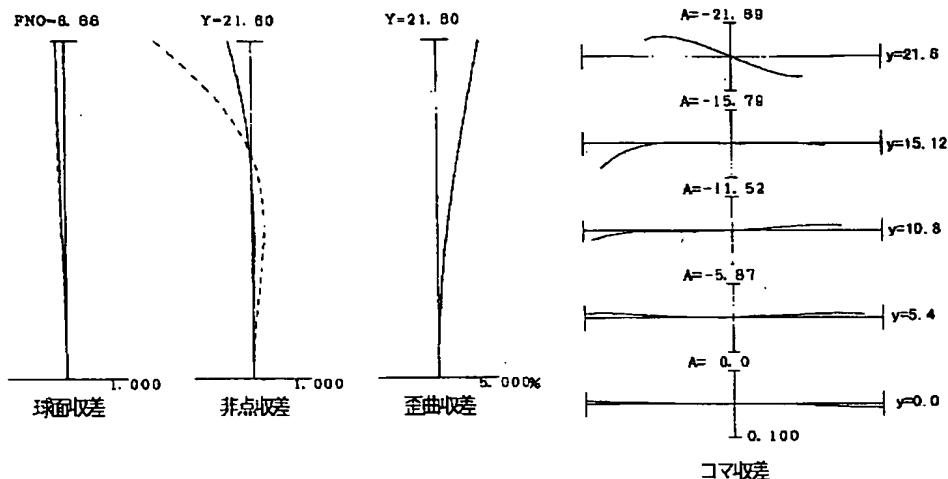
【図9】



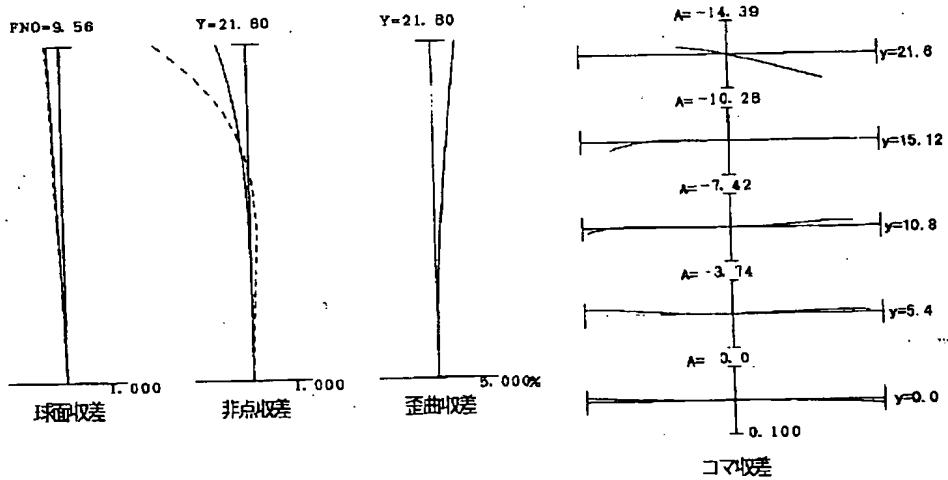
【図10】



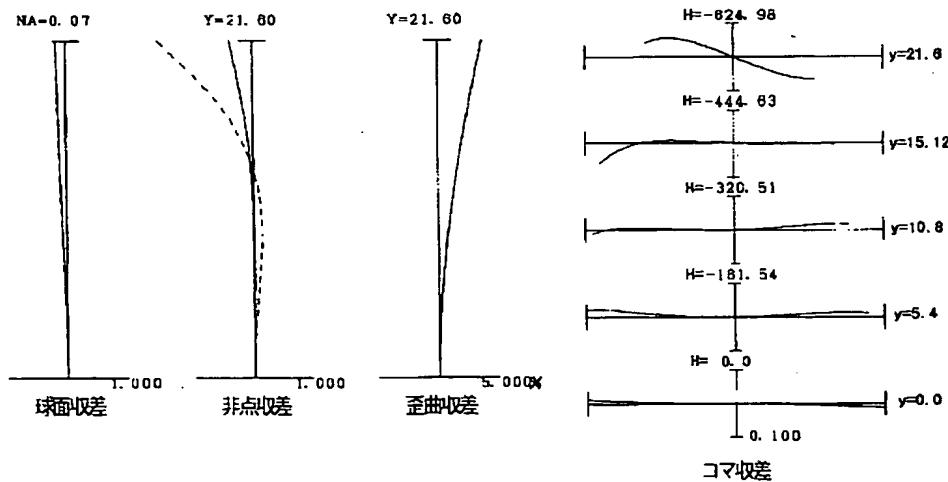
【図11】



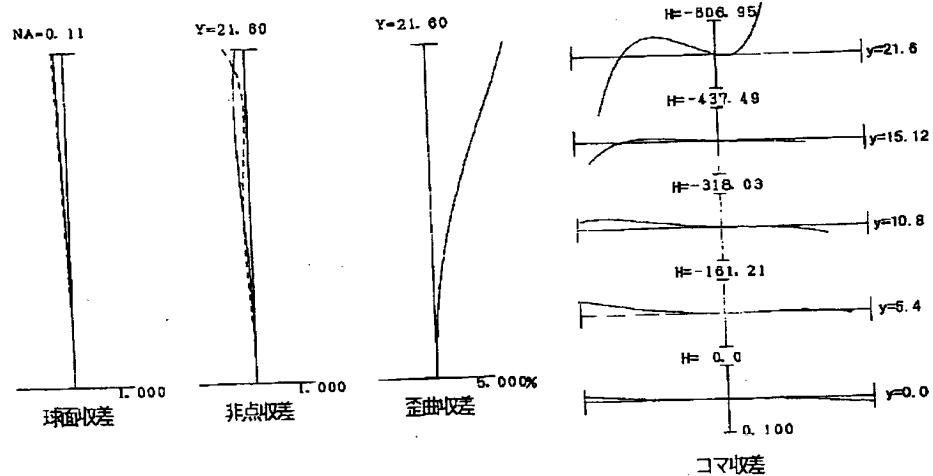
【図12】



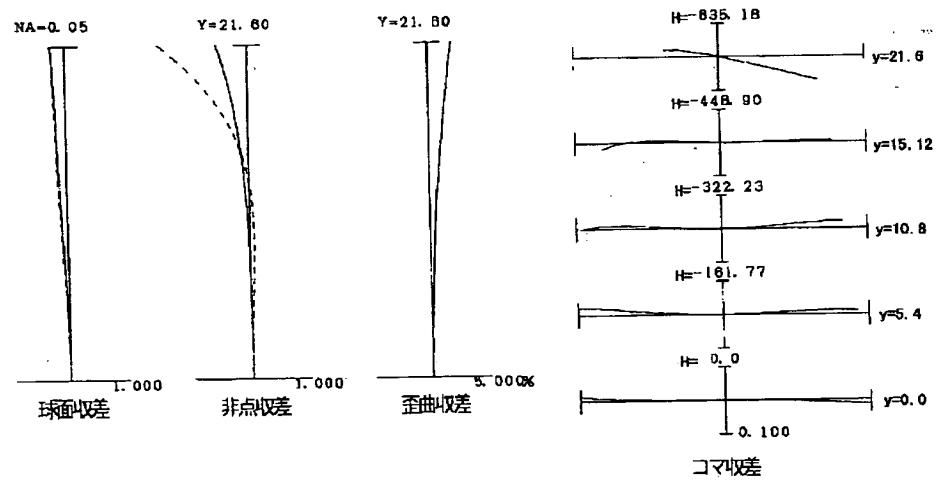
【図14】



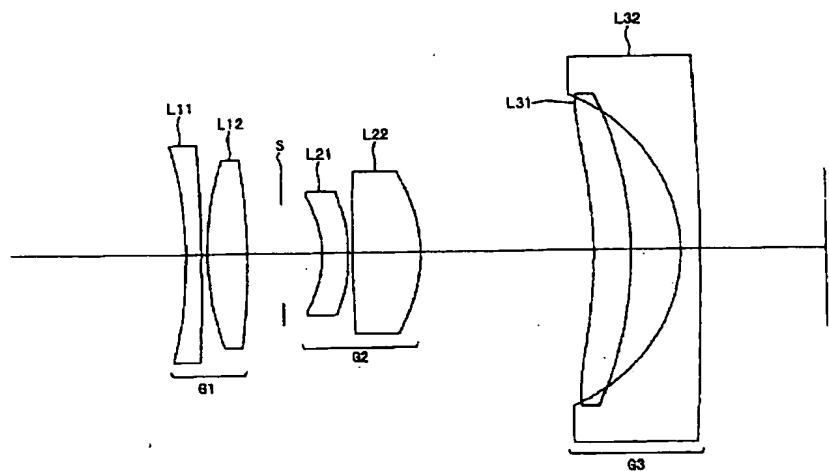
【図13】



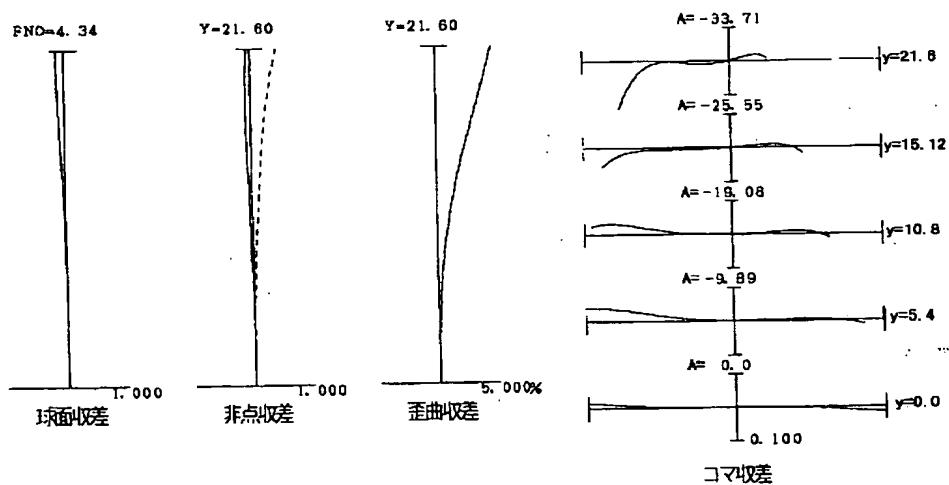
【図15】



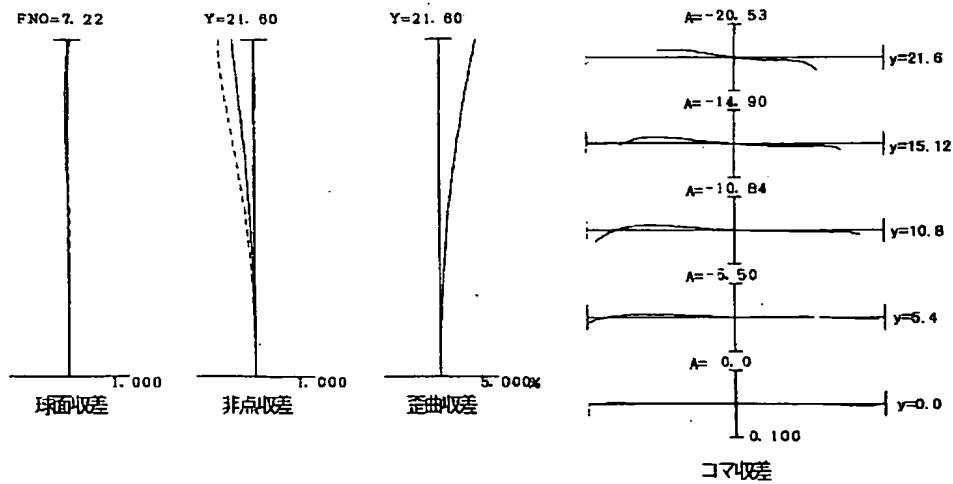
【図16】



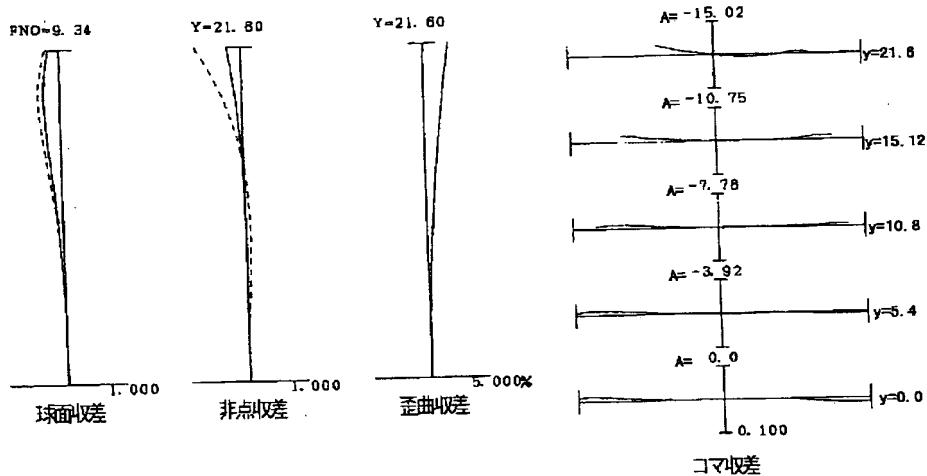
【図17】



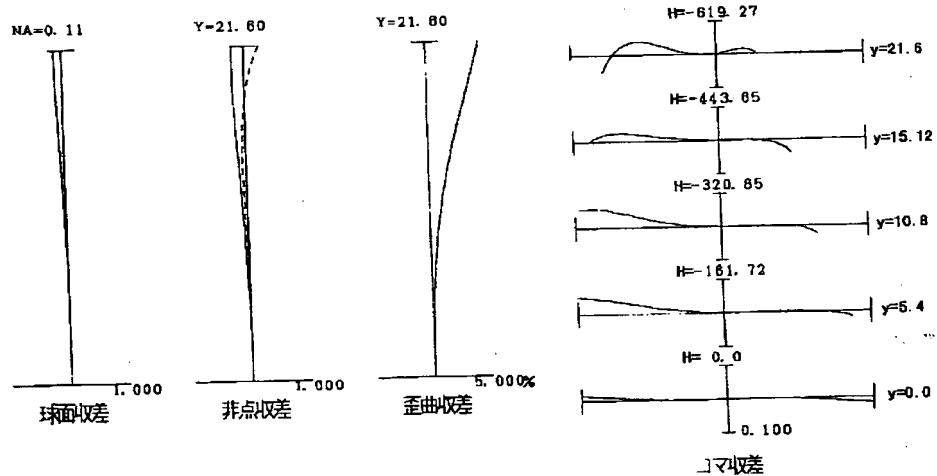
【図18】



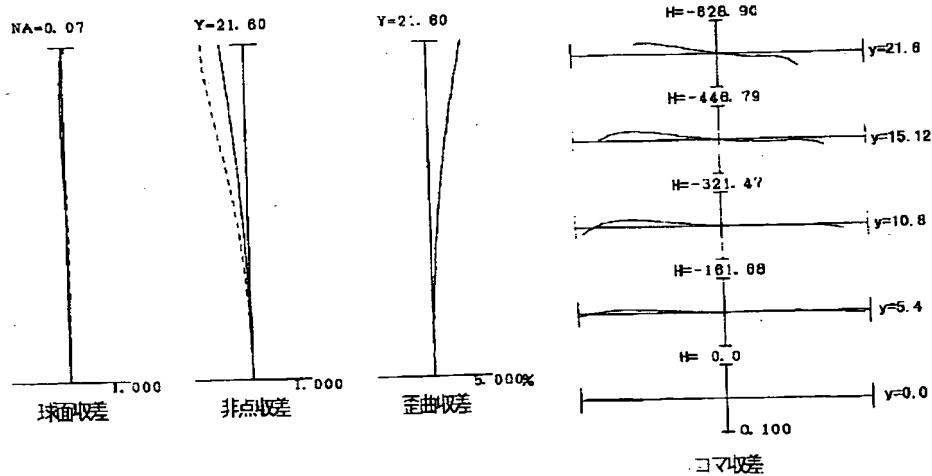
【図19】



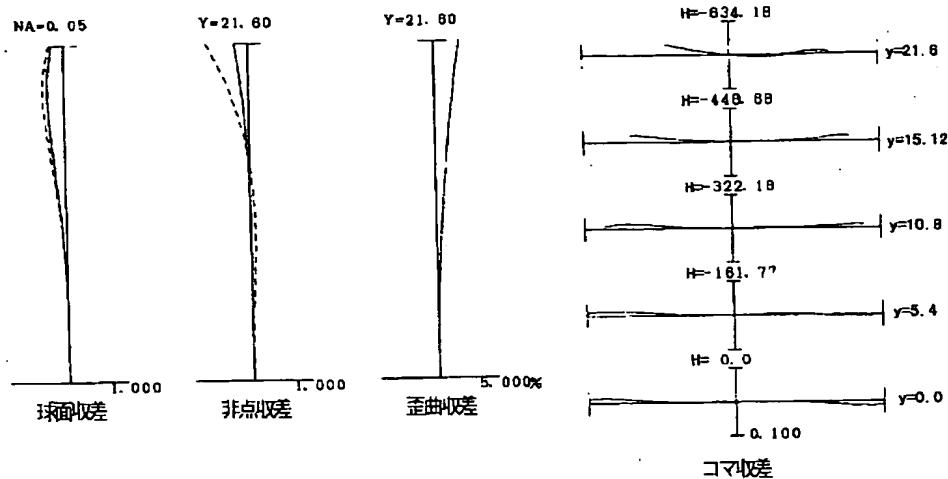
【図20】



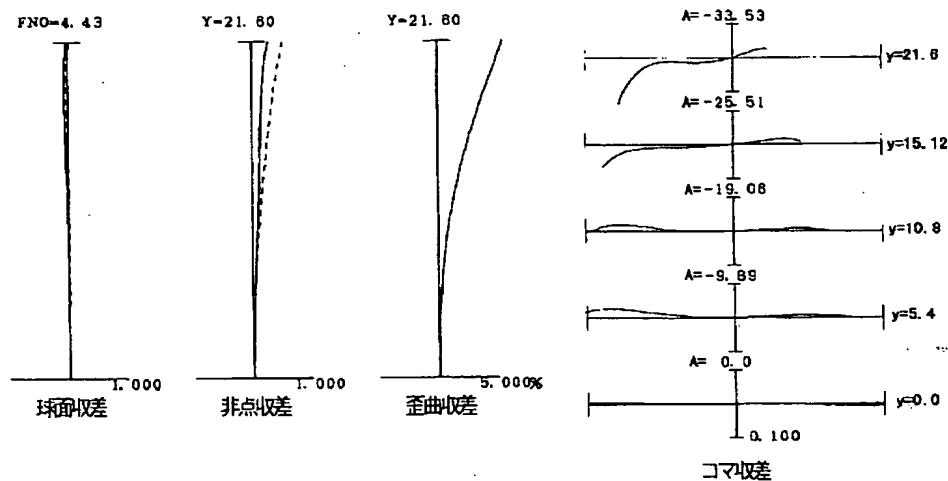
【図21】



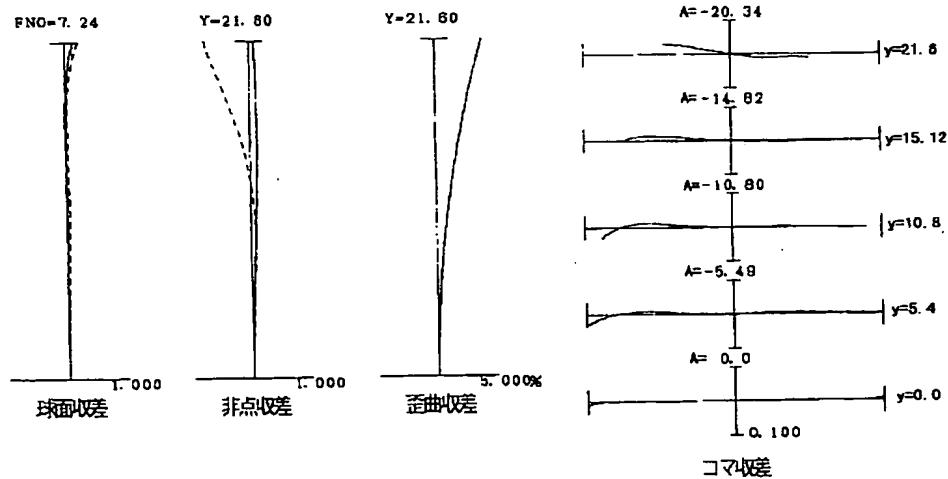
【図22】



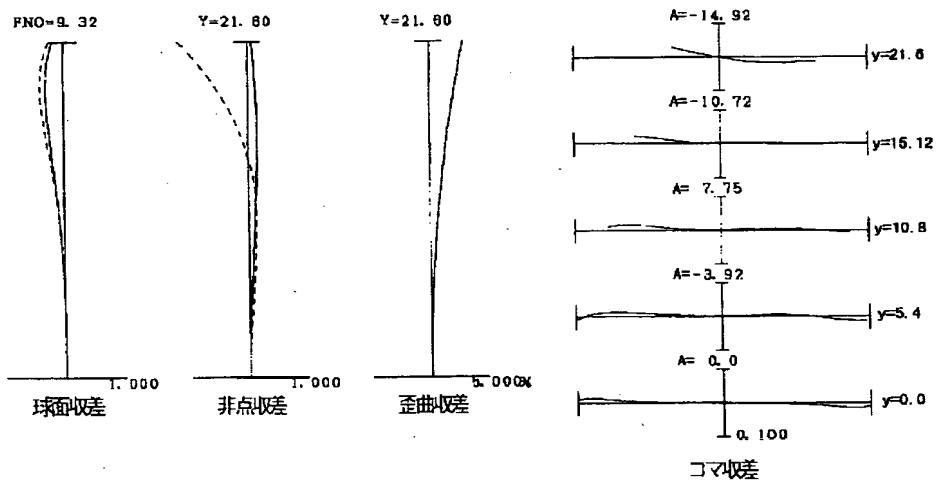
【図24】



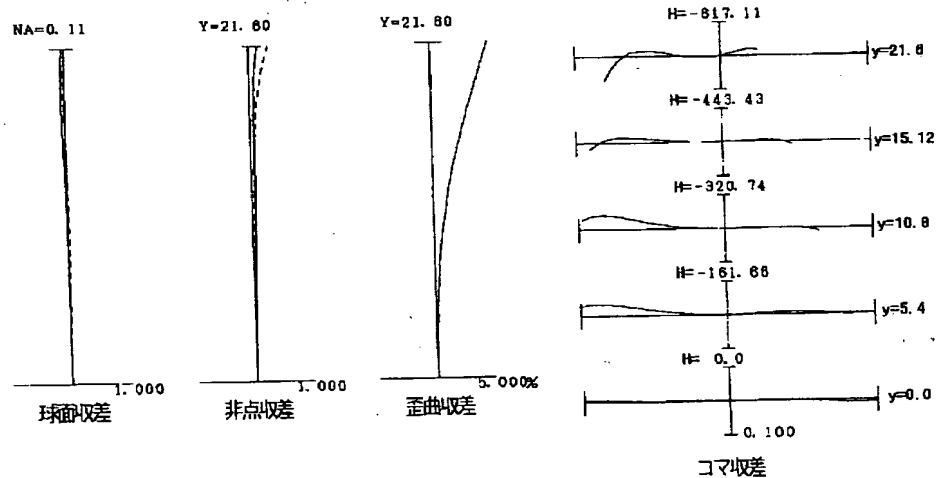
【図25】



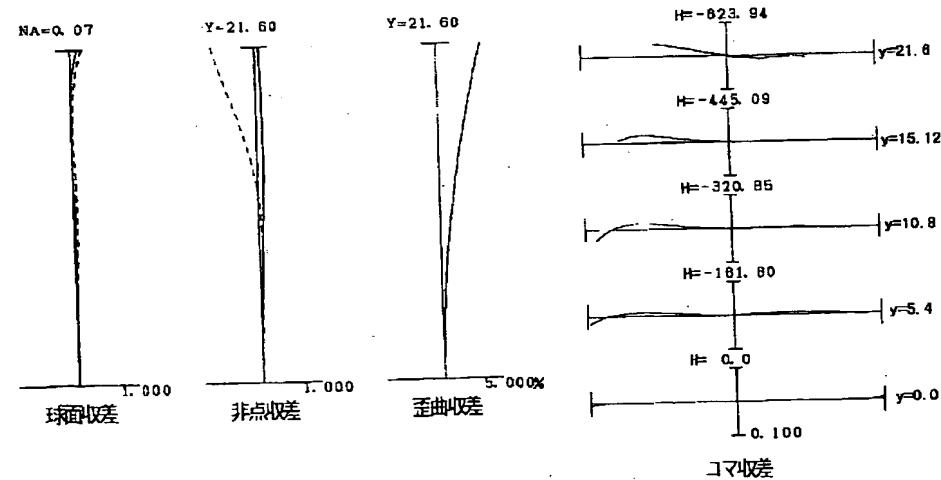
【図26】



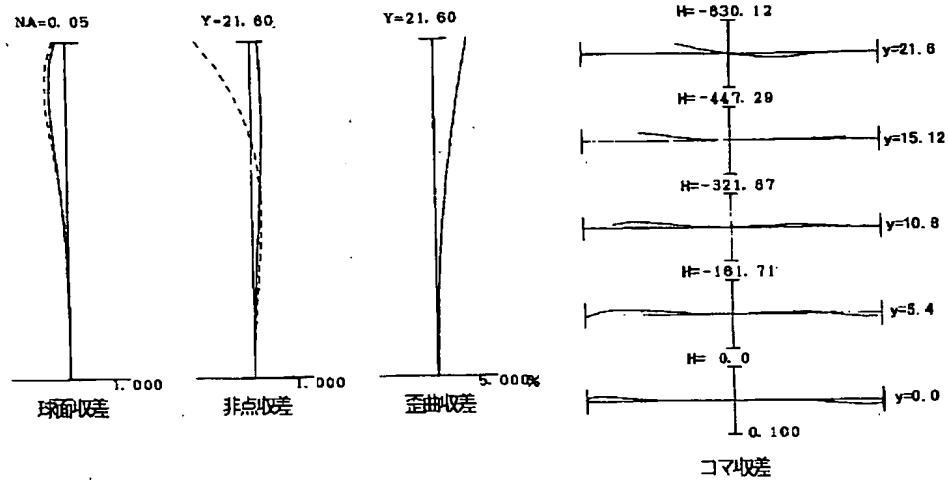
【図27】



【図28】



【図29】



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